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TECHNICAL REPORT

WHITE OAK LABORATORY

ENVIRONMENTALLY COMPATIBLE AIRCRAFT CRASH AND RESCUE TRAINING FACILITIES

24 OCTOBER 1975

NAVAL SURFACE WEAPONS CENTER
WHITE OAK LABORATORY
SILVER SPRING, MARYLAND 20910

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With the increasing sophistication of aircraft has come a corresponding increase in payload of weapons, fuel and cargo which is reflected in a potential increase in accidents and fires. This report is concerned with development of training facilities and techniques to enhance the capability of firemen in coping with their fires, while still maintaining a reasonable level of environmental impact. Training objectives are reviewed and next page

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evaluation criteria are discussed. Location and operation of training facilities are analyzed from a cost - effectiveness viewpoint. Three levels of training facility are described, ranging from operation to sophisticated, to fulfill requirements for training requirements on a local, regional or national basis. It is concluded that the essential facilities can be realized within the environmental constraints, but additional cost-benefit analysis is recommended.

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ENVIRONMENTALLY COMPATIBLE AIRCRAFT CRASH AND RESCUE TRAINING FACILITIES

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October 24, 1975

24 October 1975

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ENVIRONMENTALLY COMPATIBLE AIRCRAFT CRASH AND RESCUE TRAINING FACILITIES

This report is the result of a joined effort by the Naval Surface Weapons Center and the Stanford Research Institute under contract N60921-75-C-0184. The work was sponsored by the Naval Facilities Engineering Command under Task Area YSL56. The report is concerned with the development of techniques and facilities to enhance firemen training while minimizing undesirable environmental effects. Recommendations are made which will result in a substantially improved training program.

LEMMUEL L. HILL
By direction

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1.0 INTRODUCTION

1.1 The Fireman's Dilemma

Successful aircraft crash fire suppression and rescue requires a prompt effective action that all too often exceeds existing capabilities. Furthermore, this difficult task is becoming even more challenging with the evolution of modern aircraft and airfields. Larger, faster planes mean a greater payload of weapons, fuel, passengers or cargo and an increase in the potential for serious fires. Also, the required runways are longer - a factor that lengthens the response time.

Simultaneously with this growing need for more effective firefighting, impediments have developed to interfere with adequate training of the firemen. Encroaching urbanization and the accompanying environmental constraints on air and water pollution are limiting both the magnitude and frequency of traditional training fires. New training approaches are required to solve the firemen's dilemma by providing the greater skill that comes with more practice and experience while reducing the environmental impact to an acceptable level.

1.2 More Training--Less Smoke

This report is concerned with the development of techniques and facilities to enhance fireman training, while ameliorating the undesirable effects on the environment. The scope includes a series of questions covering the whats, hows, whens, and wheres of training that demand answers before the facilities can be designed. Sections 2 and 3 deal with the "what training" first by briefly reviewing aircraft ground accident/incident records to justify the types of fires selected for training purposes and second, by establishing a series of objectives and priorities for the training efforts. In section 4 the problem of "how to train" focuses on equipment constraints imposed by the needs for (1) motivation and stimulation to avoid boredom and (2) yardsticks to evaluate the training and to certify performance. The more amorphous questions of "when and where to train" involve operational and monetary decisions that suggest a variety of options which are outlined in section 5. Finally, the

specifications for specific training devices and the incorporation of these units into training fields designed to minimize the environmental impact are considered in sections 6 and 7 respectively.

2.0 HISTORICAL BASIS FOR TRAINING NEEDS

2.1 Incidence of Aircraft Fires

Navy, Air Force, and civilian records of aircraft incidents involving fires during the past 5 years were examined to insure inclusion of the pertinent fire problems in our recommendations for training and facilities. The records used were one short paragraph computerized summaries and thus do not constitute an extensive accident study. Nevertheless, the results tabulated in Table 2.1 provide an adequate basis for the identification of training needs. Particular points of concern were the class of fire, its location, status of the aircraft at time of fire, the cause, and the seriousness of the fire. Fires occurring in flight were excluded from the tabulation unless the aircraft reached the ground at a location where firemen could suppress the fire. When fires could be listed under more than one heading, e.g., the location involved both the crew and passenger quarters, only one listing is included; in this case, under passengers.

Of course, the types of aircraft influence the type of distribution of fires in the Air Force, Navy and Civilian categories. For example, Class A compartment fires are more prominent in civilian areas than in the Air Force and the Navy. Navy Class A fires generally involve brakes and tires or combustible structural components in the fuselage or wing. Most of the Class B fires involved leaking or spraying fuel in the engines caused by defective components or improper maintenance. The same causes were prominent in the Navy fuel system fires, i.e., fuel lines and fuel tanks. Electrical, i.e., Class C fires aboard the Navy planes occurred with the same frequency as those of the Class A category involving tire and structural combustibles.

2.2 Suggested Classes of Aircraft Fires for Training Programs

Based on the results of the review of aircraft incidents involving fire, the following list was prepared as an enumeration of the practically different situations that require separate consideration in a comprehensive training program:

- o Class A -- compartment fires only
- o Class B -- large pool, crash-fire situation -- engine fires (semi-enclosed) -- spraying or cascading fires in the open.
- o Class C -- compartment fires only

- Class D -- fires involving wheels, tires and brakes.

Two factors are reflected in this selection: (1) the frequency of the prototype accident and (2) the consequences, i.e., the potential for loss of life and property involved in each fire category. For example, crash fires involving large quantities of burning fuel are rather rare. Many air stations fortunately operate for years without such an occurrence. Nevertheless, the consequences of such potential accidents are the principal raison d'etre of airport crash/rescue services and a major factor in the design and selection of fire fighting vehicles. Their low frequency of occurrences, however, means that firemen cannot depend on real emergencies to maintain their proficiency; therefore, training exercises become a vital factor in preparing for the rare but serious emergency. Similarly, class A compartment fires are included in the list because of the potential for large loss of life and equipment, but the rest are present because of their high occurrence frequency. These fires include all of the situations listed in Reference (1) under Field Practice Rescue and Extinguishment.

3.0 TRAINING OBJECTIVES, PRIORITIES AND PROGRAMS

Training manuals such as Reference (2) emphasize that successful firemen are well trained, highly skilled, and motivated individuals. The programs designed to achieve these goals are based on the following objectives.

- Equipping new personnel to function efficiently on their jobs
- Increasing the effectiveness of the older personnel in their present jobs
- Preparing personnel for promotion and for greater versatility
- Developing enthusiasm, understanding, and other elements of general "Organizational Readiness."

An examination of the training course outlines in Reference (1) and (2) indicates three areas of activity in aircraft fire fighting and rescue training:

(1) The accumulation of knowledge about the facets of fire protection and suppression, e.g.,
   (a) Fuels, their environments and the potential fire characteristics

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(1) NAVMAT Instruction 11320.11
(2) U.S. Navy Aircraft Fire Fighting and Rescue Manual NAVAIR 00-80R-14

(b) Aircraft structures, airfields and their operation
(c) Firefighting and rescue equipment, agents and techniques
(d) A variety of operating procedures

(2) Application of the knowledge through problem solving. Emergencies and fires exhibit a multitude of permutations; therefore, the response must be tailored to the challenge presented by the particular fire.

(3) The development of physical ability in the use of equipment and the application of techniques.

A properly designed fire ground should contribute to all three areas although problem solving and physical skills will be the principle beneficiaries. These requirements imply several design features. First, there should be flexibility in setting up the fire problems so the trainees can be presented with a variety of thought provoking challenges. Second, it should be possible to exercise the training devices as often as necessary to develop and maintain the desired level of physical ability and competence. Third, the challenge should be commensurate with the fires to be expected in real emergencies, i.e., comparable skills and efforts should be required to deal with the training and the real fire. Finally, the facility should permit a quantitative measurement of performance so that the trainee can evaluate progress, his performance can be certified and the potential for promotion can be evaluated. The Training Program described in Reference (1) may be used as general guidance to basic minimum requirements but this should be updated to include specific training aids, devices, and quantitative measures ("yardsticks") of performance. Training stations should also make maximum possible use of concepts that reduce waste and environmental impacts.

4.0 EVALUATION, CERTIFICATION, AND MOTIVATION

4.1 Need for Uniform Standards

An essential requirement of any Navy program of fire fighter certification that intends to achieve standardized levels of performance and proficiency is a set of objective tests and criteria. Although these needs have been met traditionally through subjective evaluations (usually judgmental in nature) made by experienced fire officers and training instructors, the results have not always been an unmixed success. In some situations there can be little doubt that errors have been perpetuated by this procedure and, although the potential benefits of self-evaluation are well established in other fields of education and vocational training, it clearly never has been the goal of traditional fire training that a trainee would be able to evaluate his own performance.

The movement toward standardization and uniform criteria of professional competence for firefighters has been gaining momentum rapidly in the last few years. Its effects are certain to be beneficial not just in the metropolitan fire services, but also in the Federal Fire Service and their military counterparts. Formalized attempts to spell out professional qualifications (such as NFPA 1001) are useful but fail to quantify performance; that is, to provide "yardsticks." The Navy will do well to establish and promote the use of such yardsticks, showing, thereby, an example that a national accreditation program might follow to ultimately bring the fire services of the Nation to a truly professional status.

In this report, we view the yardsticks of performance in the somewhat restricted sense of tests of training achievement and as training aids. The concept is, however, readily extended to the broader context of professional competence. Yardsticks of performance may be readily perceived for rescue operations but the scope of this report is limited to fire suppression.

An indispensible ingredient of training programs in which standardized yardsticks of performance are employed is a reproducible fire. Obviously, it is impossible to compare hot-fire suppression results from one man to another, one team to another, one day to the next, or between programs in different locations until we can insure that each fire has the same characteristics and is equally difficult to suppress and extinguish. Many variables are involved, some of them more susceptible to control than others. Thus, there are quality control problems that must be given attention if one is to ensure a satisfactory level of standardization in training fires.

The training variables are those subject to operator (trainee) control-such variables as agent application rates, patterns, and densities. Measures of efficiency (the yardsticks of performance) will be times to control and amounts of agent required, when actual fires are involved. As noted later in this report, a training program can achieve its goals of proficiency within acceptable scheduling constraints with minimal waste, personnel risk and environmental impact through the planned use of judgment- and motor-skill-developing exercises ("cold fireground" practice) prior to the actual hot-fire trials. Yardsticks of performance in these exercises obviously cannot include such measure of effectiveness as times to control and the like. These yardsticks must be replaced with more thoughtfully and ingenuously devised substitutes. They will include such skill-achievement measures as uniformity and density of agent application; remote articulation of monitor nozzles, application of fire ground hydraulics, team coordination, and response time.

4.2 General Prescription for Yardsticks

In setting up yardsticks of performance (for either hot or cold fire-ground exercises), it is essential to have a realistic and

standardized scale and it is important to know the physical limitations toward which all improvements strive and often approach, may even reach, but can never exceed. The scale can be established by keeping numerical scores for repeated trials using firemen and firemen trainees at different levels of experience and training proficiency. The physical limit; that is, the end of the scale, is difficult to define in a general way and much more difficult to establish with complete confidence. An example of such a limit is the so-called "critical application density" for AFFF applied to pools of burning aircraft fuels. Application density is the applied quantity of AFFF divided by the total area of fuel burning without regard to either rate or pattern. If the agent is applied uniformly over the area, taking care in applying it not to apply in any one spot, not to miss the pool, and to keep the stream well down on to the pool surface to minimize loss of agent through lofting in the buoyant plume, there is a minimum amount-the critical application density--that will just barely suppress the fire. Its value, as determined through extensive research, is about 1 gallon of AFFF solution for each 100 square feet of burning JP-5. Most professional firemen are unable to achieve 3 gal/100 ft^2 without special training (that is, to suppress a large pool fire without using more agent than this) and equipment design can be the limiting factor that will prevent achieving anything near the critical density no matter how well trained the operator is. These factors must be considered in the process of setting up the yardstick scales.

4.3 Proficiency Levels

Certification of a fire fighter, instructor, or fire officer is to be made at several basic levels (e.g., the NFPA 1001's Firefighter I, II and III) and for numerous specialties as appropriate to the fire fighter's responsibilities. In particular, for aircraft crash and ground fire suppression and rescue operations, the traditional requirements for a knowledge of general subject matter apply but in addition, the fireman must have demonstrated the basic fire fighting skills (structural fires as well as aircraft fires) and then he must become proficient in the special techniques of aircraft fire fighting and be familiar with the special problems encountered in qualifying for each type of vehicle. Standard, comprehensive, and continuous training must be provided for all personnel through on-the-job training (OJT).

Fire officers and instructors should have special training in a fully equipped regional fire training school, since they will be responsible for the training of their own men and for the application of training yardsticks appropriate to their own operations. In addition to OJT, fire-service personnel should be tested periodically to ensure continued proficiency and as a mechanism for advancement in rating. Again, the need for objective and quantitative measures of performance is obvious.

4.4 Incentives for the Group and the Individual

Incentives to maintain and improve performance are of two distinct kinds:

(1) Group incentives that are fundamentally rooted in esprit de corps -- pride in one's own team unit - and the competitive spirit that animates and perpetuates sports.

(2) Individual incentives that, in addition to those derived from the inherent competitive nature of man, include peer recognition and financial reward.

Successful training programs will make maximum use of both of these. Some training tasks are best accomplished as unit exercises while others are best left to individual activity. Practical exigencies, to be discussed later, may force a firefighter to train in an ad hoc unit other than the one to which he is ordinarily assigned. Lacking the element of esprit de corps, it may still be possible to generate a high level of incentive to strive for performance goals through competition. Certainly, repetitive drills can become tiresome and the training activity may quickly degrade to a perfunctory exercise if suitable challenges are not introduced. The need for thought provoking, problem solving, exercises has already been mentioned.

Another challenge is brought about through numerical scoring and the keeping of intramural (or possibly intermural) records of such scores. A system of handicaps might also be employed as is commonly done in some sports such as golf or bowling. Note that only through the use of training yardsticks can such numerical scores be gotten and only through the development and use of uniform standards will there be general acceptance of these scores. One can readily imagine several ways of formally recognizing the achievements of groups and individuals: e.g., awards dinners, unit citations, achievement trophies.

The universally compelling incentive for individual achievement is take-home pay. Within the Federal Fire Service there are three mechanisms for financial recognition of performance: (1) the GS ratings themselves, (2) in-grade merit increases, and (3) accomplishment awards. Promotion from one GS level to the next should be specifically geared to training yardstick scores with allowance for specialization and for the acceptance of responsibilities not specifically designated in the position description. It would seem appropriate also to recognize good individual training scores with merit salary increases and accomplishment awards.

5.0 TRAINING SCHEDULING AND LOCATION

Answers to the questions about when and where to train will exert a substantial impact on the design of the training facility.

Vital considerations such as the number of facilities use factors, degree of sophistication, and cost are involved. Sufficient information is not at hand to provide the answers immediately; therefore, this section looks at the known constraints and options and outlines the additional information required for a logical decision.

5.1 Constraints Imposed by Existing Station Locations and Operations.

In the contiguous 48 states there are about 40 Navy and Marine Air stations, most of which are located along the coast lines as indicated in Figure 5.1a. As of April 1975, these stations were manned by 4557 civilians, 820 Navy, and 689 Marine firemen of which about 2000 to 2400 were assigned to crash and rescue. It is customary to cross train the firemen so that the structural crews can provide backup or assistance in crash fires; therefore, the training facilities should accommodate the entire crew. Major stations will have 50 to 100 billets while small or part-time installations may have only two dozen. Normally, the firemen are divided into two 24-hour shifts that work a 72-hour week. Training practices vary considerably, e.g., from hot fires once a month to once a quarter or less. Training exercises are frequently conducted during periods of minimum aircraft activity; however, the location of the drill ground normally permits a state of standby or backup alert to be maintained throughout the training, i.e., each station has its own drill ground. Several forces are at work to modify this state of affairs. First, the solution to atmospheric pollution may be too costly for a large fire training installation at each station. Second, pressures to change the work week may alter the manning levels and thus the availability of firemen for training during their regular shifts. These factors, along with changes in the types of fire trucks, i.e., P-4's are now being ordered for the Navy should be considered in examining the various training location and scheduling options.

5.2 Training Location Options

Table 5.1 lists various training options along with their advantages and disadvantages. If viewed according to the motion required to reach the training grounds, the options can be divided into 3 groups.

- o Take the training to the fireman
- o Take the fireman to the training
- o A blend of the first two

The first category offers two possibilities. A training facility at every station or a traveling facility that could serve about 10 stations per quarter allowing a week per each. Since a portable large area pool has not been discussed before, the feasibility not only would have to be established on the basis of the economic and

operational pros and cons but the mechanical practicability would also have to be demonstrated. Figure 5.2 illustrates the concept generated for the comparisons in Table 5.1, i.e., a group of modules that could be quickly assembled or disassembled and moved in the manner of carnival or circus furnishings. Transporting the training to the firemen minimizes disruption to the station schedule and equipment at the expense of use factor, initial cost, and contact with other firemen.

Three general "moving the firemen" options are considered based on the extent of cooperation involved between agencies; (1) neighboring Naval stations use a single training facility as suggested in Figure 5.1a by the solid circles that include station within a 100 mile radius of a central fireground, (2) neighboring DOD or DOD + civilian fire departments as indicated by the dashed circles in Figure 5.1b, (3) regional facilities from 2 to 4 in number serving the entire Navy, DOD, or DOD + civilian. Obviously, the degree of scheduling and the potential for additional manpower requirements increases with the number of fire departments sharing the facility. The pros and cons in Table 5.1 for this category assumes that each crash truck crew trains as a unit at the neighboring facility on the basis of a one day trip per quarter while firemen would probably go individually to the regional center and stay several days on a less frequent schedule. Two possibilities are available to avoid undermanned stations on training days (1) the neighboring stations could exchange fire crews or (2) training could be covered by overtime and pay. These sharing options minimize the initial construction costs and increase the use factor but introduce new operation and maintenance problems. Since it is impractical to drive crash and rescue vehicles between stations on a routine basis, the training would presumably involve vehicles at the host station. Two problems arise with this procedure (1) the host station inherits an increased maintenance load and (2) cooperation between Navy, Air Force, and civilian departments is complicated by their different styles of trucks. Presumably regional facilities would acquire their own trucks, provide arrangements for maintenance, and establish a resident training staff.

The third category of options permits various combinations of local and cooperative training where the shared aids are the hot fire bed and perhaps the enclosed fire facility. Most of the pros and cons listed in Table 5.1 relate to various aspects of station disruption and cost. Both of these factors depend on training frequency and in this age of austerity, our thinking focuses on the practical minimum rather than a comfortable maximum.

The Federal Aviation Administration's Advisory Circular No. 139.49-1 (dated 11/12/74) "Programs for Training of Fire Fighting and Rescue Personnel" lists the following frequencies for practical training subjects.

Subject	Suggested Frequency
a. Inspecting, cleaning and maintaining the aircraft fire fighting and rescue equipment by the driver/operator. This should include a "walk-around" type of inspection plus a starting/operating check for safe and effective operation.	Daily
b. Testing communications equipment, battery levels and battery charging equipment.	Daily
c. Crew familiarization training in the operation of vehicles, the fire fighting and rescue equipment.	Monthly
d. Topography training and vehicle driving exercises involving the aircraft surface maneuvering areas on the airport. This should include the use of primary and alternate routes for response, exercises during daytime, nighttime and periods of low visibility, plus checking gates in the airport fences.	Quarterly
e. Orientation training on aircraft, principally of the types operating at the airport, assisted where feasible by airplane representatives. This should include aircrew evacuation methods and means for occupant escape/rescue, aircrew extraction, entrance doors, emergency exits, cargo compartment doors, emergency slides and the procedures in Air Force Technical Order 00-105E-9 pertaining to commercial aircraft.	Semiannually or more often if new aircraft become operational at the airport.
f. Familiarization training between the airport fire services and municipal fire services surrounding the airport.	Semiannually
g. Individual/crew practice on live-training fires.	Semiannually
h. Drill or practice on breathing apparatus, forceable entry equipment and first aid methods.	Quarterly

i. Training for crew/vehicle response according to outline in par. 5a and 5a(4), AC 150/5210-11, with response to the midpoint of the furthest runway from the assigned post within 3, 4, or 4 1/2 minutes, as applicable. (Experience gained by military services on the safety aspects of test exercises indicates that such tests should be prearranged with appropriate airport authorities. In this case, it is suggested that the exercises be conducted by airport management and coordinated with the fire department units involved). — Semiannually

All items except subject g. can and should be conducted on-station. Hopefully, the hot-fire trials (item g) can be conducted more often than semi-annually. It is clear, however, that achieving and maintaining a standard level of proficiency requires frequent and intensive training. If regional centers are employed, the once-a-year training would provide a good opportunity to evaluate performance and certify proficiency but more frequent practice is required to maintain performance at its peak. It is desirable for crews that work together to train together, and if training sites are close enough (say within 50 to 100 miles) to the regular duty station, then it should be possible to schedule a one or two-a-year off-station training activity for each unit <u>as a unit</u>. In any event, it must be scheduled well in advance so that nothing less than a catastrophy will interfere. Allowing four hours for commuting, four hours of intensive training by a regular unit may be worth more than eight hours for an individual assigned to an ad hoc training unit.

On the other hand, there may be outweighing advantages to detaching one crew member at a time for training TAD. Obviously, whenever travel distances are excessive, the latter alternative is preferable to prolonged force depletion. In any event, it is less disruptive to the home station (no more than that resulting from annual leave), and it may make the operation of the regional site easier and more efficient. The relative benefits and disadvantages can be learned only through experience.

5.3 Cost-Effective Analysis of Alternatives

Table 5.1 discusses the various training options in qualitative terms that do not readily indicate the merits of one system over another. A cost-effective analysis is needed to complete the comparison.

The objective of such analysis is to establish a quantitative economic basis for planning and decision making. It seeks

to optimize the augmentation of on-station training programs and facilities with shared training facilities, focusing primarily on such variables as the number and location of such facilities, the size and complexity of facility development, and the possible combinations of interservice and civilian utilization. Such practical constraints as travel time and off-station time, perceived and actual environmental impacts, and budgetary limitations must be imposed as boundary conditions on the analysis. The basic output of the analysis is the cost (both potential and actual) per effective trainee-hour achieved. Moreover, (given the input of data not presently available) it can be made to include: (1) an economic assessment of the tradeoffs between remote siting (whenever possible) and sophisticated equipment designed to reduce environmental impacts; and (2) the best cost/benefit mix of "cold" and "hot-fire" training techniques. Here we include a preliminary example of such an approach where most of the numbers are guesses or at best very rough estimates, used to obtain costs for each of the options listed in Table 5.1. Starting with the air station distribution in Figure 5.1, the cooperative groupings are tabulated in Table 5.2 for naval stations alone and combination navy and air force training centers. Based on these groupings, Table 5.3 summarizes the rough estimates for (1) the original construction cost for the number of units required, (2) the costs to move firemen to training for a year and (3) the number of years for the operating costs plus the initial construction to equal the cost of a facility at every station. Various assumptions employed in arriving at these estimates are listed in the footnotes at the bottom of the Table. Since reliable estimates of initial construction costs will require design data not now avaiable, three estimates are used to indicate the impact of the degree of sophistication employed in the design. In the final analysis, for example, a blend of designs would probably be employed as suggested in section 6. In the interests of economy, the range could extend from kits to be assembled by the firemen or the public works department to completely furnished multiple units at a regional center. Also a studied operating figure should make allowances for the rapidly increasing inflationary costs. These detailed considerations go beyond the scope of the present report. Here, our purpose is to indicate the options available, their general impact on costs and the need for a financial analyses before a final decision is reached. However, the analysis will undoubtedly exhibit the same trend encountered in our illustrative example, namely, that the cooperative use of facilities at the neighboring or regional level is financially advantageous over short times but the converging cost functions imply that ultimately it will be as economical to provide every station with a facility. The useful life of the facility now becomes a factor in evaluating the convergence time. Historically, fire training has evolved slowly and the changes that have occurred do not appreciably alter the fire required, therefore, a useful life for the facility should be at least 25 years. By that time, the art of simulation may eliminate the need for large real fires.

Another fact to be considered is that fire training is not just a Navy problem-it is a national problem effecting civilian and military air fields alike. Therefore, we must prepare plans that can be pursued unilaterally by the Navy or be amalgamated into tri-service programs, or national-level programs that might grow out of the activities of the recently formed National Fire Prevention and Control Administration. In planning for a National Fire Academy the NFPCA has already contacted the FAA, AGFSRS, NASA, the Federal Fire Council, IAFC, and the Joint Council of National Fire Service Organizations to determine requirements for national training programs including training for aircraft and airfield fire fighting and fire protection. An ultimate outgrowth of this activity could be the establishment of National Fire Training Centers.

Even if a national fire-training program is established offering regional training centers and satisfying the most demanding requirements and specifications set forth by the Navy, it will still be necessary to have local training facilities accessible to the personnel assigned to each Naval Air Station to allow them to maintain proficiency through frequent training exercises. To what extent this must include hot-fire suppression and rescue trials is, at the moment, unsettled and controversial, but there appear to be numerous training activities that do not involve actual (or large) fires whose returns in skill achievement are good and can surpass hot-fire exercises in relation to their relative costs. More work needs to be done to assess the cost/benefit tradeoffs between hot-fire exercises and their cold-fire counterparts used either supplementary to hot-fire trials or in lieu of them.

6.0 TRAINING AIDS AND DEVICES

Section 2 identified five pertinent types of fires based on the combustible material and the environment which was dominated by the degree of enclosure. The next two sections considered general training requirements and yardsticks for evaluating performance. This section combines all of these requirements plus the constraints of minimal environmental impact into recommendations for training devices for suppression of four types of fires. Since the design of a device is dictated by the intended use, each discussion commences with a list of training exercises for that device.

6.1 Class A Compartment Fires (Interior Fuselage Fires)

6.1.1 Specific Training Objectives and Exercises with Interior Fuselage Fires-The training objectives are:

- o Regular and forcible entry practice
- o Exercise in use of air packs, and protective clothing during rescue and fire fighting operations.

- Practice in safetying the various aircraft systems, e.g., engines, O_2, electrical, ejection, etc.

- Extinguishment practice on Class A fires both from inside and outside the compartment, i.e., penetrating applicators would be used from the outside.

- Rescue of occupants

6.1.2 Fuselage Fire Trainer Specifications-Aircraft accidents can generate all degrees of confinement ranging from the initial airtight fuselage to wrecks where the fuselage is torn wide open. In the sealed case, smoke and heat are confined and the flames may be smothered for lack of oxygen. At the other extreme, there may be little resemblance to a compartment fire. Two degrees of confinement or ventilation are suggested for the trainers (1) an airtight compartment corresponding to the undamaged fuselage without ventilation and (2) a compartment with an air throughput corresponding to the normal ventilation on passenger carrying aircraft, e.g., 1/4 change of air per minute. The compartment should be equipped with standard openings for normal entry and replaceable panels for forcible entry cut-ins.

Three components dominate the interior of a burning aircraft fuselage; (1) the flames to be extinguished, (2) the combustion products, i.e., smoke, hot gases, and toxic products that interfere with visibility, breathing, and approach to the fire, and (3) the compartment contents, furnishings, passengers, cargo, etc. that obstruct motion, may need to be rescued or can contribute to the fire. All three ingredients should be present in the training device; however, the hostile elements should be well controlled to provide reproducible environments. Two general approaches to training are available; (1) let the fire generate its own heat, smoke and products or (2) control the components individually. While the first approach bears the marks of authenticity, the second may provide more flexibility in setting up a variety of training problems, i.e., fires in various positions and involving different rates of smoke and heat buildup. While smoke and heat are essential challenges and air packs would be used during the training, toxic products are not necessary and should be minimized by a careful selection of fuels and combustibles. In other words, the visual effect is usually all that is required for training purposes. Appropriate temperatures and smoke levels will have to be determined for the various training problems; however, a range can be estimated from the air available for combustion and some NASA test fires in the passenger compartment of a Boeing 737. In the sealed compartment case, the O_2 supply would limit the energy release to about 45 BTU per ft^3 of air space. In a fuselage 10' in diameter by 15 ft long, this maximum release would be 53,000 BTU or the equivalent of burning about 1/2 gal of JP-5. Black smoke levels could

limit the visibility of a 100 watt light bulb to about 4 ft. Burning rate and flame sizes would depend on the fuel and its configuration and would have to be determined.

6.1.3 Suggested Training Devices--Reference (1) suggests the use of salvage aircraft fuselages in training with forcible entry tools and fire suppression procedures. Figure 6.1 shows a fuselage or a fuselage section modified for training with Class A and C fires. All openings can be sealed to permit an O_2-starved fire. Normal entry procedures use the regular aircraft opening (Item 1). Forcible entry with cutting tools is practiced on replaceable panels (2) bolted onto the fuselage at prescribed entry points. These panels can be sections cut from other salvage aircraft parts or sheets of metal. Additional experience and agility with the cutting tools can be obtained by using the tools to prepare the supply of panels. Similarly replaceable patches (3) are available for practice with penetrating applicators. Smoke abatement and air control during the ventilated burns depend on the exhaust fan (4) the air inlet damper (5) and the chevron baffeled scrubber (6). Also, the fan can be used at reduced speed in the sealed aircraft exercise after entry has been achieved to provide a slight inflow through the opening to carry the smoke to the scrubber. A supply of movable obstacles, i.e., passengers (simulated with mannequins) in seats (7) or cargo (8) permit rescue training and fire fighting with impediments in the way. Empty O_2 bottles (9) and electrical batteries (10) are included for safetying practice. Finally comes the fire (11) and its products, heat (12) and smoke (13). Both of the fire approaches mentioned in section 6.1.2 will be examined during the course of this study.

The choice of fuel deserves further attention but discarded rubber tires will be selected for the present illustration. Rubber is easily ignited, generates copious quantities of black smoke and heat, and provides a reasonable simulation to burning electrical cables or plastic foam upholstery. Extinguishment is readily accomplished with H_2O although the char layer that forms requires penetration and cooling to prevent reignition. Several locations in the fuselage are selected as burn areas (11) and a good insulation (14) such as Kaowool, Fiberflax or possibly mineral wool is applied to the adjacent interior regions of the fuselage to prevent damage to the aluminum. A thin steel or stainless steel covering over the insulation prevents mechanical and H_2O damage. Water sprinklers (15) at each burn site provide control of the burning rate in order to force the heat buildup to approach the planned heating curve. When necessary the sprinklers can also control or extinguish the fire. After each training exercise, the hot, smokey air exhausts through the scrubber to remove smoke and pyrolysis products. While the scrubber design will require additional thought and information, the system offers an opportunity to recycle used water and thus reduce the total water that must be reclaimed or suitably discarded. All of the water in the trainer used for fire regulation and suppression plus the water in the

scrubber can come from the class B fuel-water separation tank. The slight AFFF contamination will not interfere with any of the H_2O functions, in fact the slight foaming and improved wetting action of the surfactant may improve the smoke collection in the scrubber.

When class A fire environments are simulated, heat and smoke are separately controlled. The flames for suppression could be provided by a NTEC type computer controlled simulator (16) Reference (3), not much larger than the current demonstration model. Smoke could be generated by a smoke grenade or by burning some JP-4 or JP-5 (17). If additional heat is required to establish the desired thermal insult it could be provided with a regulated gas burner (18). While the computer controlled simulator approach would be more expensive than burning rubber tires, the level of extinguishment difficulty is readily adjusted and quantitatively controlled by the computer. Therefore, the fire environment is both more flexible and reproducible than free burning fires.

Other possibilities include the use of neutral density filters over the face masks to simulate smoke obscuration and relatively smokeless alcohol or acetone fires to generate heat. However, these liquids are not appropriate for extinguishment practice because of their substantially different response to agents used on conventional aircraft fuels, e.g., foam, halons and H_2O.

6.1.4 Yardsticks for Evaluating Performance in the Class A Compartment Simulator-Time is the most important factor in the procedures to be mastered as listed in Section 6.1.1, i.e. the time to bring the breathing apparatus into operation, the time to perform a forcible entry, the time to safety the O2 and electrical systems and rescue the crew or passengers and finally the time to control the fire. In addition to control and extinguishment times, the amount of agent applied provides a good measure of efficiency.

6.2 Class B Large Pool Fire Crash Situation

6.2.1 Specific Training Objectives--The training objectives are:

- To develop efficient qualified operators of air craft fire fighting and rescue vehicles, e.g., MB-1, MB-5, TAU's.
- Measure proficiency in suppressing large area pool fires with turrets and hand lines.

(3) NAVTRAEQUIPCEN. IH-241 "Feasibility Demonstration of a Non-Pollutant Synthetic Fire Fighting Trainer" B. E. Swiatosz, W. S. Chambers and P. D. Grimmer, Dec. 1974

- o Establish proficiency in rescue operations

6.2.2 Cold Fire Ground Specifications-The training objectives in Section 6.2.1 suggest a two stage program where first the vehicle operation is mastered and demonstrated on a "cold" fire ground and second, the hot training fires are the final step in establishing a rating or qualification.

A major problem in the efficient use of AFFF for extinguishing pool fires is the application of a uniform layer of foam. The critical application density is the amount of foam that will just extinguish the fire, e.g., for JP-4 and JP-5 this critical application density is about 1.5 and 1.0 gal/100 ft^2 respectively. Foam footprints with existing turrets are not uniform and the maneuverability adds to the difficulty of producing a uniform foam layer. Consequently, the total foam applied frequently averages 10 to 20 times the critical application density. Efficient foam application with the truck nozzle requires well trained muscular action to overcome poor visibility and to anticipate the foam trajectory, e.g., to avoid overkill, the nozzle should be moved before the foam completes its trajectory. Therefore, the trainer should employ regular crash vehicles and agents. There should be an unlimited supply of agent so the practice can continue until the desired proficiency is achieved. Variable boundaries and obstacles should be introduced to simulate the variability encountered in real aircraft accidents. Finally, the evaluation of each performance requires provisions for measuring the application pattern, the uniformity, and the application density.

Figure 6.2 shows the essential features of a "cold" fire training pit and several possibilities for construction. The waterproof training area (1) drains into a foam settling basin (2) where the foam solution is recovered and returned to the training vehicle for reuse. Distinctive boundary markers (3) outline a series of simulated fire bed shapes to provide practice in foam pattern control. Sampling pans (4) or load cells collect foam for the analysis of application uniformity. Various mockups and obstructions (5) can be introduced to make the foam application more challenging. Finally, a motion picture camera or T.V. Tape camera (6) records the application pattern for subsequent analysis. The time consuming steps in cold fire training are removing the foam from the test area to the drainage pit and measuring the application density and uniformity. Several procedures have been used to remove the foam: sweep or squeegee, blow with air, wash with water or collapse with a foam breaker. The best procedure will depend on the construction selected for the pit area and the degree of sophistication selected as indicated in Figure 6.2.

6.2.3 Hot Fire Ground Specifications-Reference (4) lists the 11 items reproduced in Table 6.1 as considerations that should be incorporated in any aircraft training fire facility. The list is very inclusive; therefore, the job here is to translate qualitative terms such as "sufficient" and "demonstrate" into measurable quantities. Items 1 and 2 deal with the fire's intensity and realism, i.e., factors strongly related to fire size.

In a test situation, the fire size and intensity are controlled by the type, amount, distribution and motion of the fuel along with the substrate and obstructions in the environment. However, the atmospheric conditions, particularly the wind, must be accepted as they come and it is difficult to produce two fires that are exactly the same. An unperturbed deep pool fire (in calm weather) develops the largest size, has the hottest radiation field, burns the fastest and is the most difficult to extinguish. Winds and porous substrates reduce the fire intensity and simplify extinguishment. Therefore, a simulation or training fire that matches the unperturbed pool fire represents the most difficult case. The training fire should approach the prototype sufficiently to present the same challenge and require the same effort to extinguish. Definitely, the fire should be large enough to reveal the differences in techniques and performance. Also, the size of the fire truck and aircraft influence the appropriateness of the fire size. For example, a MB5 with a 250 GPM discharge rate could theoretically cover the 2000 ft^2 minimum area suggested in Table 6.1, with the critical application density for extinguishing JP-5, i.e., 1 gal/100 ft^2 in 4.8 sec. An MB1 with twice the discharge capacity would only require half as long.

Table 6.2 lists typical Navy, Air Force, and civilian aircraft according to size as indicated by wing span and fuselage length. Many of the fighters would fit reasonably well into a 50' dia fire but the patrol, cargo, and bomber types in the 100 to 250 ft category would overwhelm such a fire bed. These considertions of realism, equipment, and aircraft argue for large sized training fires; however, considerations of pollution and cost, both initial and operating, speak for small fires. The 50' dia fire represents a compromise that is fairly reasonable for most Navy situations. Two alternatives are available to increase the apparent fire challenge without significantly changing the pollution factor and cost.

- First, a movable mockup can be used around the edge of the fire as indicated in Figure 6.3. In practice, two or more trucks normally respond to a crash and attack the fire from two sides or ends depending on the environmental limitations.

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(4) Smoke Abatement for Open Area Aircraft Fire Rescue Training "Training Fire" of October 1974 10F/DET

In principle, each truck has to extinguish only half the fire; therefore, for training purposes, simulating half the emergency and restricting the rescue approach to the maximum path through the fire would make the most of the available fuel. This procedure is particularly appropriate for large aircraft where the fuselage forms an effective barrier dividing the fire in two.

o Second, the divided fuel arrangements illustrated in Figure 6.4 can cover a larger area with flames than the same fuel in a single pool. This technique is routinely used by the Air Force at Chanute to simulate crash fires on uneven terrain where the fuel would normally spill and collect in a random collection of pools.

A combination of the movable mockup and divided fuel pools would provide the controls suggested for the training officer under item 3, Table 6.1.

The IITRI "Spray-water" system for generating a reasonable smokeless pool fire is being considered and tested for hot-fire training purposes. In other pool fire situations the pollution abatement and extinguishment challenge have been acceptable; therefore, there is reason to believe the system will be adequate for aircraft crash and rescue training. The present Joint Air Force/Navy test program involves two parts (a) a human factor evaluation comparing the spray-water fire to its unsprayed prototype for effectiveness in suppression training and (b) optimizing the design features of the facility. Presumably the spray-water system eliminates smoke by reducing the burning, i.e., to about 2/3 to 1/2 of the unperturbed value; therefore, it is imperative to establish that the suppression requirements are not significantly altered. Fortunately, smoke is not as important in aircraft crash fire training as in enclosed fires. Normally, the truck will attack the fire from upwind or cross-wind and the foam stream should always be applied to the leading edge of the flames; therefore, vision is not obscured and the smoke can be sacrificed for environmental purposes. Two types of information are required in the human factors evaluaation of the spray-water fire: (1) the influence of the change in fire characteristics on the fundamental suppression requirements and (2) the impact of the altered fire on fireman performance - the forthcoming tests at Chanute should distinguish between and satisfy both of these requirements. Both the spray-water and the prototype fires should require the same critical application density of AFFF for extinguishment and an additional amount of foam should provide the same burn back protection. In order to minimize the fireman performance factor in obtaining these fundamental factors, we suggest the drive-by technique for measuring the critical application density and burn back resistance. The effect on fireman performance both with the truck turrets and hose lines should be compared for the

spray-water and prototype fires on the basis of extinguishment time and agent required in addition to subjective factors influencing performance.

6.2.5 Mockup Specifications--We begin this section by examining the functions of the mockup. By definition, a mockup should add some or all of the complications to the fire expected from a real plane, i.e., it provides:

- An obstruction that interferes with the straightforward application of agent to the pool fire.
- Fuels of various types and distributions. For example, aircraft contain class A, B, C, and D fuels and the liquid fuels may be flowing, spraying, dripping, etc.
- Ignition and reignition sources. Hot surfaces or flaming class A components can reignite the liquid fuels.
- A focal point for rescue efforts
- A major source of variability that makes one fire different from another.

These functions agree with the requirements listed in Table 6.1 under items 4, 5, and 6. Several considerations are involved in translating these functions into a design suitable for the hot bed training. First, two general approaches to rescue are required to cope with the aircraft listed in Table 6.2. In fighter planes and other small aircraft rescue is achieved without entering the fuselage, i.e., canopies are opened or removed to reach the crew. In the large craft such as bomber, cargo and passenger planes, rescue involves entering the fuselage to reach the victims. Second, a real crash scene can involve all of the fire types listed in section 2.2, i.e., class A, B, C, and D; therefore, the hot bed training exercise could be orchestrated as a grand rehearsal covering all aspects of the firefighting crash and rescue operation. A suitable balance must be selected between combining all the training into a single exercise and drilling on the individual steps. Third, economic considerations will limit the use of the hot bed training device more than the other fire simulators; consequently, more practice and presumably more proficiency could be achieved in the aircraft rescue training or the suppression of engine fires by using specific trainers for these functions.

Bowing to economics and emphasizing the availability of the other training devices, the mockup specified here is designed to provide flexibility in the obstructions, fuel and ignition categories, i.e., factors pertinent to the training and testing of fire truck operation and extinguishment but of minimum benefit with

respect to rescue. The mockup illustrated schematically in Figure 6.3 is sized according to a small fighter appropriate for a 50 ft dia pool. Flexibility in setting up fire problems is achieved by mobility and provisions for several moving fuel fires. Where wind directions are fairly reliable, the rotating mockup offers simplicities both in articulation and plumbing over the translating version.

6.2.4 Yardsticks to Evaluate Performance in Extinguishing Class B Pool Fires--For cold-fire tests, the yardsticks are:

- Ability to lay down a prescribed application density
- Application uniformity
- Application pattern

For hot-fire tests they are:

- Extinguishment time
- Amount of agent required for extinguishment

6.3 Class B -- Spray Fires

6.3.1 Specific Training Objectives--Two training goals are:

- Efficient use of agents and techniques for extinguishing 3-dimensional moving fuel fires.
- Certification of skill with powder, CO^2, Halon, and other recognized powder and vapor agents.

6.3.2 Satisfactory Environment--Spray fires occur under a wide variety of open and enclosed situations; e.g., engine compartment fires which are semi-enclosed, ruptured fuel or hydraulic lines in the fuselage where the enclosure can vary from complete to open, and dripping, running or cascading fuel outside the plane structure. Two types of fires are recommended: (1) simulated engine fire where extinguishment is complicated by hot metal surfaces and obstructions but assisted by partial confinement. (2) Open cascading or spraying fire where there is no confinement for powder or halon agents: The fire size and intensity should be coupled to the size of agent dispensers, i.e., large enough to be challenging but capable of being extinguished, e.g., 6 to 20 GPM of fuel over 20 to 160 ft^2 cross section. Smoke is not essential for these cases.

6.3.3 Suggested Training Devices--As examples, the following are listed:

- Engine fire mockup - or discarded engine - adjust spray and airflow to make reasonably clean fire.
- The NTEC simulator could be configured for use in engine fire.

6.3.4 Yardsticks--Examples are:

- Time and amount of agent to extinguish
- Application pattern (from Motion Pictures or T.V. Playback)

6.4 Electrical Fires

Since class C fires in aircraft will involve solid fuels burning in confined spaces, the difference from the fires already discussed in Section 6.1 rests in the source of ignition and the added complication or hazard of electrical power. With provisions for simulating the safetying of electrical circuits and extinguishing the fires with an acceptable class C agent, the fuselage training unit satisfies the requirements for electrical fires. Again, performance would be rated on the basis of time for extinguishment and the agent deployed.

7.0 TRAINING FACILITIES

Detailed engineering design of facilities incorporating the concepts described above are entirely outside the scope of this report. Nevertheless, there are certain basic requirements imposed by conservation of natural resources and the quality of the natural environment that define criteria for site selection and suggest a minimum level of sophistication in facility design that will satisfy the requirements of regulatory agencies and minimize the likelihood of public outcry. The regulatory requirements can be met by minimizing the waste of hydrocarbon fuels and by limiting to the lowest practical level the air and water pollution impacts of the training activity. Careful site selection will reduce the chances of public interference.

With regard to air pollution (and to some extent, water pollution as well), fire-training activities do not contribute a really significant amount to the overall environmental burden; that is, the real effect tends to be more of a visual impact than an actual burden.*

Site selection criteria, therefore, should include population density, the local concentration of heavy industry, and certain demographic, topographic, and climatologic factors. Sites should be chosen to minimize the perceived as well as the actual impact on the environment. Unpopulated, remote sites are much to be preferred for this reason and this in turn favors the establishment of a few

* For this reason, night-time training has been used at some stations.

regional training sites to serve a large number of air stations, especially in the western states and the inland areas of the Gulf coast where the population density is low.

In addition to site selection, several practical measures can be employed to reduce to a minimum fuel and agent waste and air and water pollution. Provisions should be made for the recovery and reuse of unburned liquid hydrocarbons. Settling ponds can be used to good advantage for this purpose. A mechanical separator is available commercially and is currently being tested at Texas A & M to determine its applicability for fuel recovery. Such systems not only permit recovery of unburned fuel but also recycling of water, thereby reducing the waste of water and the amount of contaminated water requiring disposal.

Three general factors influence the design of the fire training ground: (1) physical considerations for weather, terrain, and the size and number of training devices, (2) operational requirements such as the number and frequency of training sessions, simultaneous or sequential operation of the devices and the number of observation and control points required for instruction and safety, and (3) monetary limitations on both the initial construction and routine training. We are concerned principally with the physical considerations; however, the operational and monetary constraints have such a strong impact on the collateral equipment used to control, store and recover water, fuel and agents that three classes of training facilities are considered; i.e., (1) a "Spartan" (austere) fire-training field suitable for small individual air fields, (2) a modest local facility shared by several fire departments or a very large department, and (3) a sophisticated facility suitable for national training of instructors or regional certification of firemen. Figures 7.1, 7.2 and 7.3 illustrate the three concepts and the differences in operation imposed by the auxiliary equipment. Since the same training devices are employed in all three cases, the physical space requirements are modified only by the difference in maneuvering room between simultaneous and sequential operation of the cold and hot fire beds. In terms of a single training exercise, the fuel, water and agent requirements are dominated by the water-spray pool fire unit; therefore, this unit will control the supply and storage requirements for the facility. Two quantities are of interest; (a) the amounts (and rates of supply) of H_2O, fuel and agent required to perform a test and (b) the amount expended or contaminated during the test so that replacement and disposal are required. Table 7.1 lists some preliminary estimates of these quantities for a single exercise on each of the five different training devices.

7.1 The Spartan Assembly

In the Spartan assembly (Figure 7.1), the requirements for plumbing and storage facilities are minimized by using fire fighting vehicles to transport, store and pump water. Costs of the Cold Fire-

Pit can be minimized by using an existing paved aircraft parking area for turret training. After each exercise, the foam can be squeegeed into a plastic-sheet-lined ditch at the edge of the paving for return to the truck. After many training replications, when the foam is well used, it could be sacrificed in a hot-fire extinguishment exercise. Water for smoke abatement in a hot pool fire could be supplied by a conventional pumper drafting from a fire plug if one is available or from a tank truck. Water and fuel consumption would be minimized at the expense of fewer fires per unit time by allowing the AFFF foam to settle out or be removed with a mechanical or air skimmer in preference to overflow skimming which removes fuel as well. Fresh fuel would be added from drums or a fuel truck to replace the fuel consumed. Water collected from the hot-fire bed overflow would be used to supply the fuselage scrubber and suppression requirements. Again, the pumper would move the water through fire hoses to minimize permanent plumbing. Fuel for the engine and cascading fire facilities would be applied from fuel drums with a portable pump or from a more substantial container under pnuematic pressure. Foam for the cold-fire-bed exercises also would employ water from the hot-bed sump and if the agent concentration became appreciable in the sump as measured with a refractometer, only sufficient agent would be added to bring the concentration up to the nominal 6%. Since recycled water is suitable for all functions except the smoke abatement spray on the hot-fire bed, the waste water to be discarded should not exceed 200 gal. per fire. This is very nominal waste in relation to the number of trainee-hours accomplished, particularly with optimal usage of cold-fire skill and judgment-developing exercises.

Undoubtedly, some AFFF can be tolerated in the smoke-abatement spray so that some recycled water could be mixed with the fresh to further reduce the disposal problem. Evaporating ponds are probably the most practical means of disposal. At stations conducting 5 or less fires per week in arid parts of the country, natural evaporation could dispose of the excess water during most of the year.

The initial costs of setting up a spartan assembly could be minimized by providing the IITRI spray pool fire and other training aids in kit form to be assembled by the firemen and/or public works. Figure 7.4 indicates a form of pool construction amenable to the "self help" kit approach.

7.2 The Modest Local Facility

The "modest local facility" category covers the range between "Spartan" and "Sophisticated" thereby accommodating considerable variation in equipment. Such facilities would be designed for about 5 to 20 hot pool fires per week with the associated H_2O, fuel, and concentrate requirements shown in Table 7.2. When training fires become a near daily occurrence, stationary pumps and tanks become more feasible than a pumper truck and water tanker. Also, with the increasing training activity, the turn-around time required to remove

the foam in both the cold pit and the hot bed becomes an important factor. The "Spartan" techniques for removing foam without transferring fuel from the pit should be adequate at least up to 15 fires per week; therefore, Figure 7.2 shows no provisions for collecting and reclaiming fuel floated out of the hot fire pit. As with the "Spartan" system, all control valves are manually operated from a ground level header feeding the various sprinkler zones. Foam application practice can be on a paved parking area or on a specially prepared cold pit as indicated in Figure 7.2. If space is limited, the crash trucks can perform cold and hot training in series so that the same maneuvering area is used in both tests. Finally, the fuselage, engine and cascading fire tests could function with either temporary hose lines and pump or with permanent plumbing.

7.3 The Sophisticated Facility

In the "sophisticated" facility, the number of tests justify more expedient procedures for removing foam between fires, e.g., the flotation technique, provisions for simultaneous operation of all training devices, and the recovery of fuel removed with the foam by the flotation. Figure 7.3 indicates these features along with an observation tower, additional storage tanks and a booth for on-the-spot replay of the T.V. coverage.

8.0 CONCLUSIONS AND SPECIFIC RECOMMENDATIONS

8.1 Better training of firemen in the art of aircraft ground fire suppression and rescue can be achieved with less smoke provided both the training procedures and the associated facilities are improved.

8.2 Three aspects of training and performance need attention, i.e., motivation, evaluation, and certification. NFPA 1001 and NAVMATINST 11320.11 provide useful general guidance to basic minimum requirements but quantitative measures of performance, referred to in this report as "yardsticks", are essential to better training. (See section 4.0). Motivation requires flexibility in the training facilities to provide a variety of challenging fire suppression problems. Conversely, evaluation and certification involve standard reproducible fires where quantitative measurements of time and agent required for suppression will have some meaning.

8.3 Facilities are required for suppression and/or rescue training in five fire situations.

- Class A and/or C fires inside the aircraft fuselage where forcible entry and breathing apparatus are essential to the operation.
- Large Class B pool crash-fires capable of challenging fireman performance with crash vehicles.

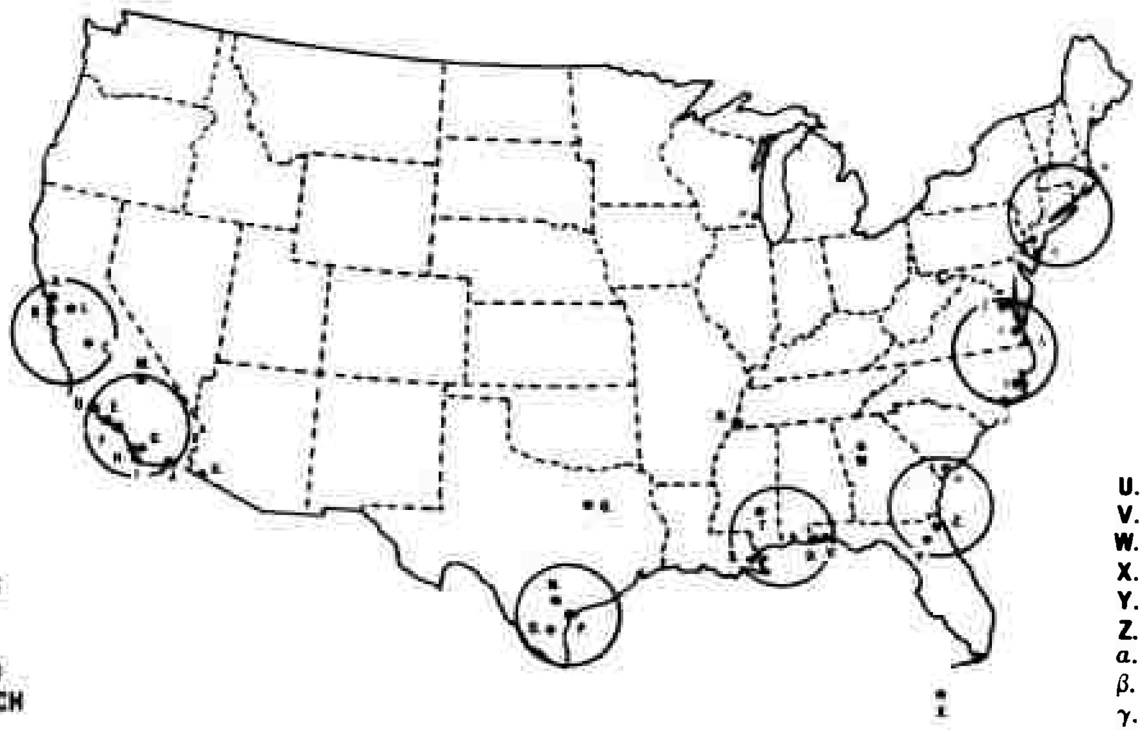
- o Class B aircraft engine fires
- o Class B cascading or spraying fuel fires
- o Class A and D fires involving wheels, tires and brakes

Five training devices are described that meet these requirements while minimizing air and water pollution.

8.4 Before the various devices can be incorporated into a facility, decisions must be reached regarding the number, frequency of use, location, and allowable cost of the facilities. For example, does every air station have its own facility or are they shared on a local, regional or national basis? The report describes three classes of training facilities, Spartan, Modest, and Sophisticated along with several alternatives for implementation on a Navy-only basis and in joint-action programs with the other military services, through mutual aid arrangements with civilian airport services, and under a possible future program guided, coordinated, and/or subsidized by the Federal Government through the National Fire Prevention and Control Administration. Presumably, planning within the Navy must proceed unilaterally; however, provisions should allow for the prospect of cooperative and national-scale fireman training programs.

8.5 An economic analysis along with an analysis of station operations is needed to decide when, where, and how training will take place. Will training go to the firemen or firemen go to the training? The illustrative example presented in section 5 suggests the following trends that should be placed on a quantitative basis by a formal analysis.

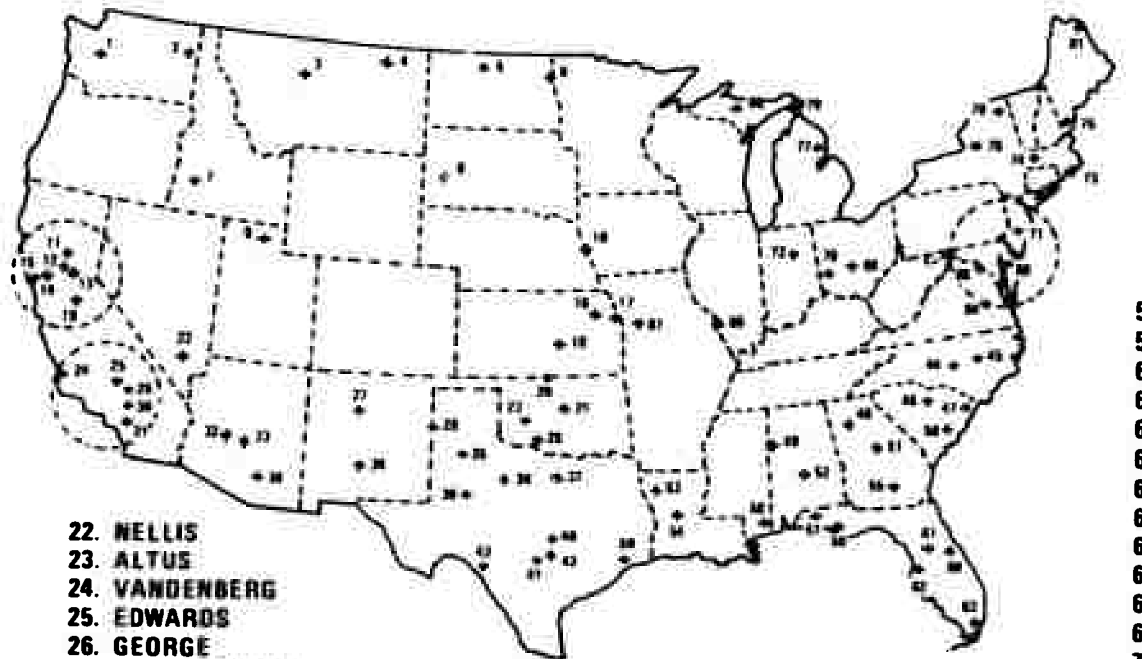
- o Minimum disruption of station activities favors a facility at each local station.
- o Uniform training and certification of fireman performance favors large regional facilities.
- o Costs for the various options exhibit a converging pattern. Overall, construction costs are lowest for shared facilities but ultimately, the higher operating costs cause a convergence with the value for a facility at every station. Quantitative values are needed for the initial separation and the time of convergence.



A. ALAMEDA
B. MOFFETT
C. LEMMORE
D. POINT MUGU
E. LOS ALAMITOS
F. EL TORO
G. MIRAMAR
H. NORTH ISLAND
I. IMPERIAL BEACH
J. EL CENTRO
K. YUMA MCAS
L. CROWS LANDING
M. CHINA LAKE
N. CHASE
O. KINGSVILLE
P. CORPUS CHRISTI
Q. DALLAS
R. MEMPHIS
S. NEW ORLEANS
T. MERIDIAN

U. PENSACOLA
V. SAUFLEY
W. ATLANTA
X. KEY WEST
Y. CECIL
Z. JACKSONVILLE
α. BEAUFORT
β. NEW RIVER
γ. CHERRY POINT
δ. OCEANA
ε. NORFOLK
ζ. PATUXENT RIVER
η. LAKEHURST
θ. WARMINSTER
ι. WILLOW GROVE
κ. SOUTH WEYMOUTH
λ. BRUNSWICK
μ. GLENVIEW

FIG. 5-1A NAVAL AND MARINE AIR STATION LOCATIONS



1. McCHORD
2. FAIRCHILD
3. MALSTROM
4. GLASGOW
5. MINOT
6. GRAND FORKS
7. MOUNTAIN HOME
8. ELLSWORTH
9. HILL
10. OFFUTT
11. BEALE
12. McCLELLON
13. MATHER
14. TRAVIS
15. HAMILTON
16. FORBES
17. RICHORDS-GERBAUR
18. McCONNELL
19. CASTLE
20. VANCE
21. TINKER
22. NELLIS
23. ALTUS
24. VANDENBERG
25. EDWARDS
26. GEORGE
27. ALBUQUERQUE
28. CANNON
29. SHEPPARD
30. NORTON
31. MARCH
32. LUKE
33. WILLIAMS
34. HOLLOMAN
35. REESE
36. DYESS
37. CARSWELL
38. MONTHAN
39. WEBB
40. BERGSTROM
41. KELLY
42. RANDOLPH
43. LAUGHLIN
44. POPE
45. SEYMOUR JOHNSON
46. SHAW
47. MYRTLE BEACH
48. DOBBINS
49. COLUMBUS
50. CHARLESTON
51. ROBINS
52. CRAIG
53. BARKSDALE
54. EGLAND
55. MOODY
56. TYNDALL
57. ELGIN
58. KEESLER
59. ELLINGTON
60. PATRICK
61. McCOY
62. MacDILL
63. HOMESTEAD
64. LANGLEY
65. ANDREWS
66. SCOTT
67. WHITEMAN
68. DOVER
69. RICKENBACKER
70. WRIGHT PATTERSON
71. McGUIRE
72. GRISSOM
73. OTIS
74. WESTOVER
75. PEASE
76. GRIFFISS
77. WURTSMITH
78. PLATTSBURGH
79. KINCHELOE
80. SAWYER
81. LORING

FIG. 5-1B AIR FORCE AIR BASE LOCATIONS

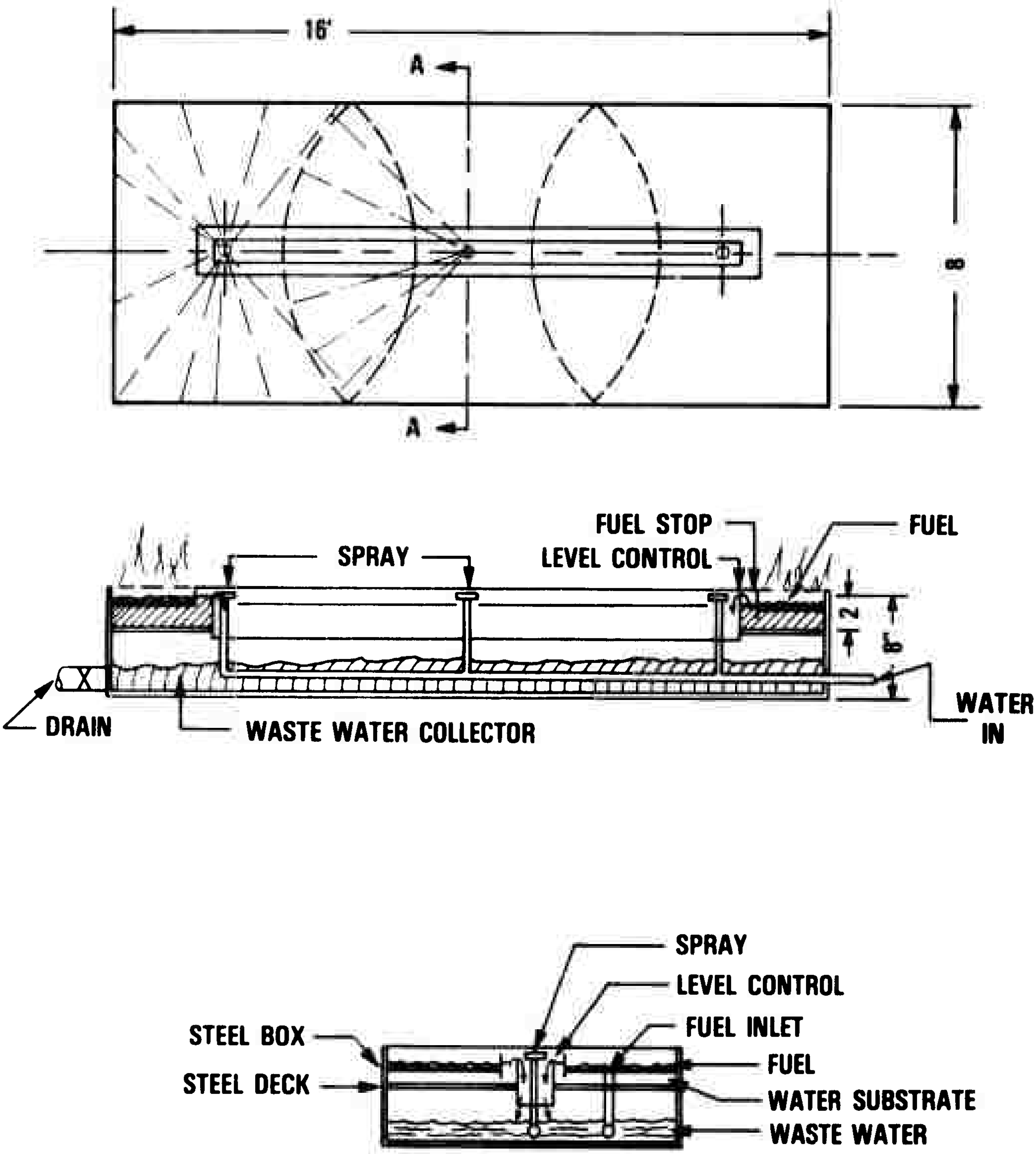


FIG. 5.2 CONCEPT OF PORTABLE "SPRAY WATER" POOL FIRE MODULE, 18 STACK ON A STANDARD 8' X 32' TRUCK BED

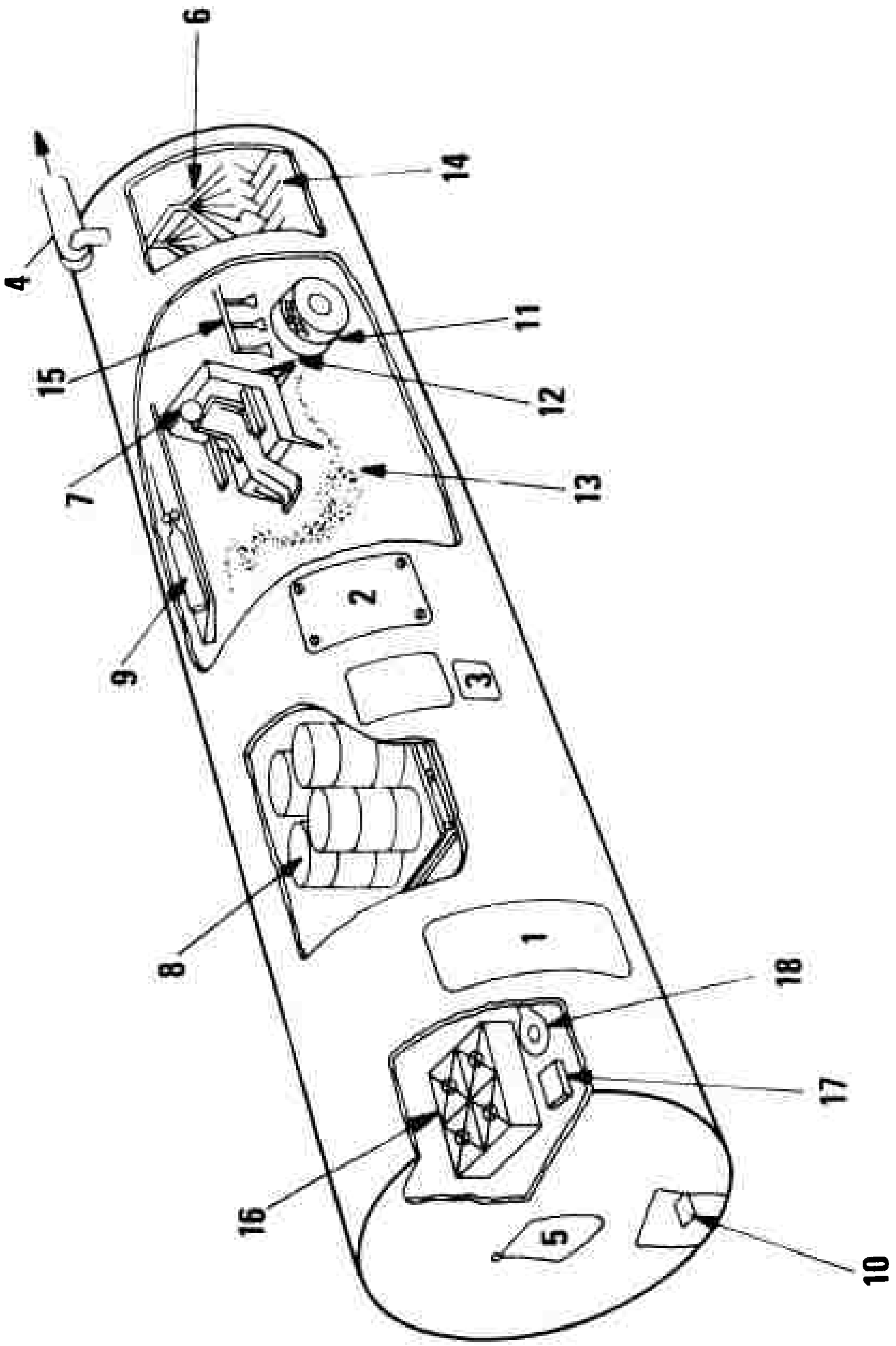


FIG. 6.1 FUSELAGE FIRE TRAINER

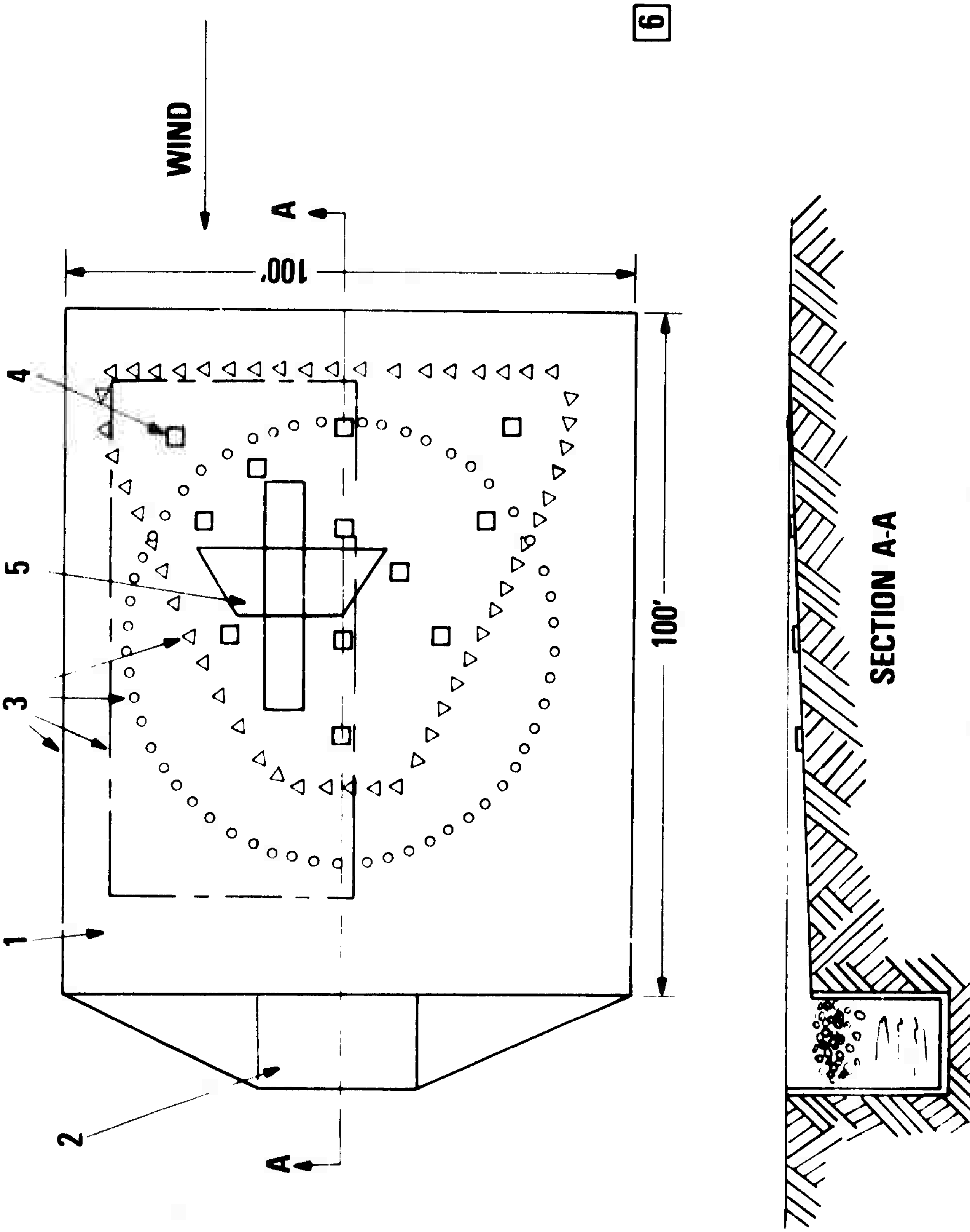
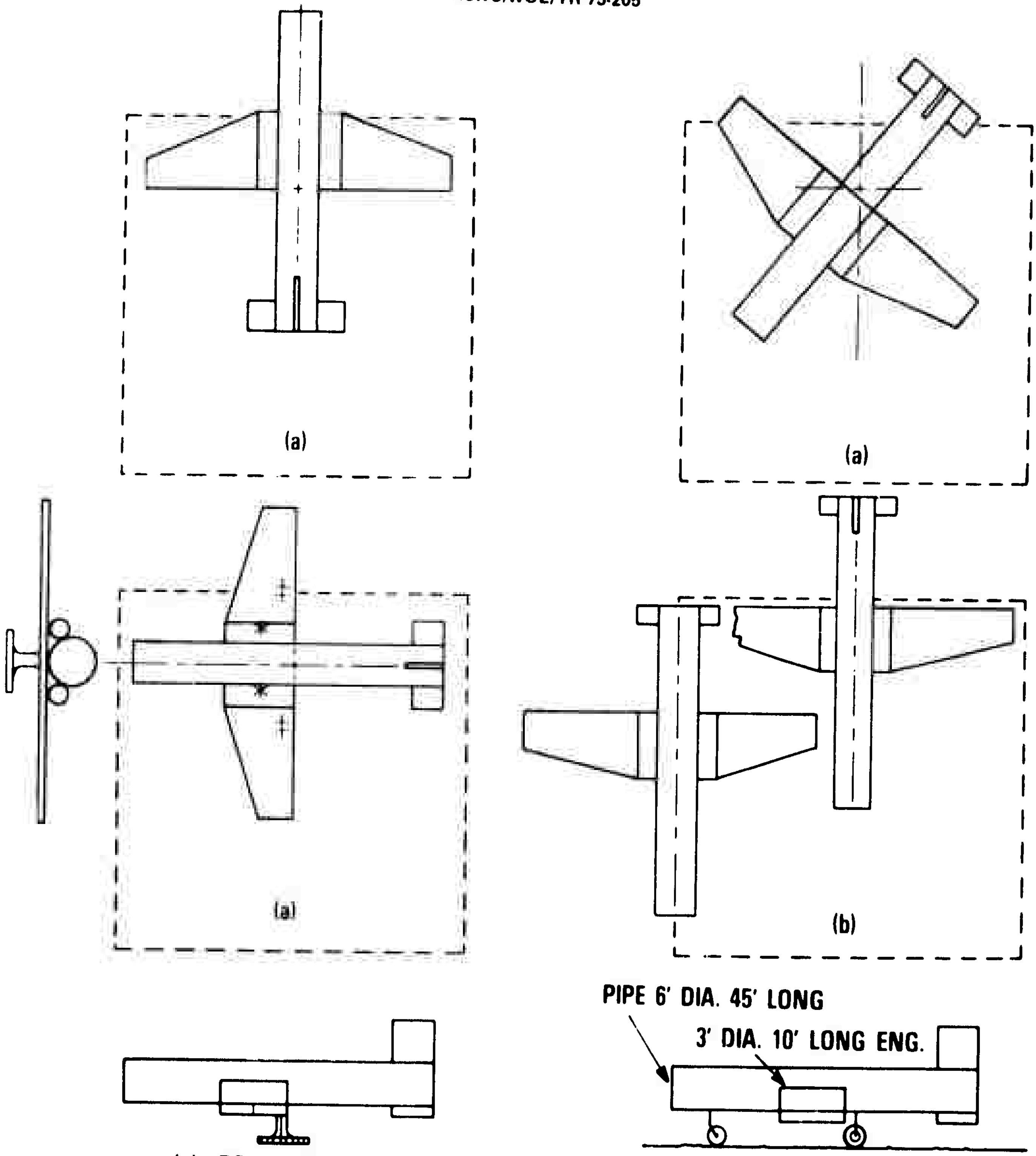


FIG. 6.2 COLD FIRE-TRAINING PIT



(a) ROTATIONAL SYSTEM ON OLD GUN MOUNT OR EQUIVALENT

(b) TRANSLATIONAL SYSTEM

* INTERNAL SPRAY FIRES AVAILABLE

‡ EXTERNAL CASCADING FUEL

FIG. 6.3 MOCKUPS FOR POOL FIRES

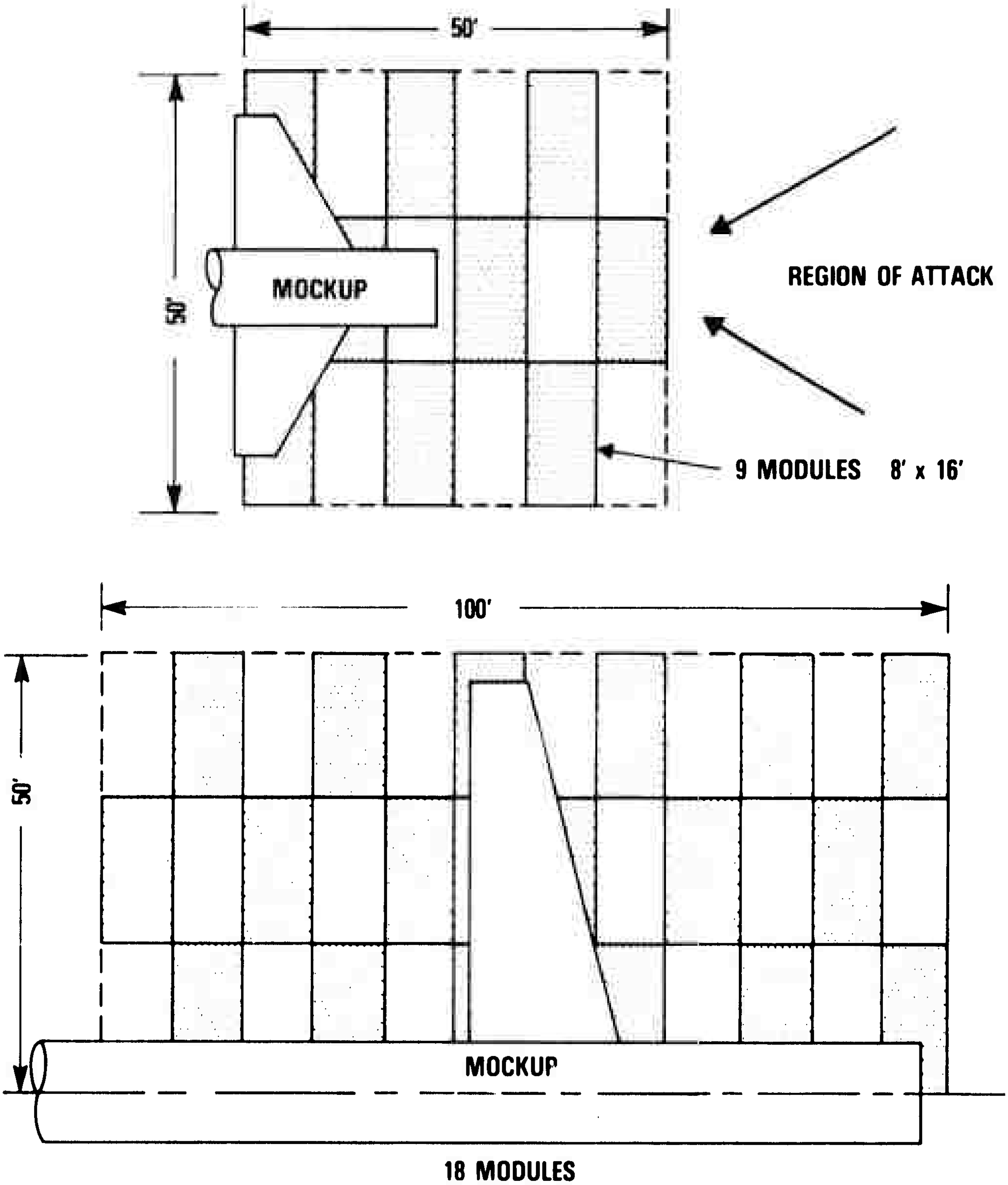


FIG. 6.4 LARGER FIRE AREAS WITH LESS FUEL BY USE OF MODULAR FIRE BEDS

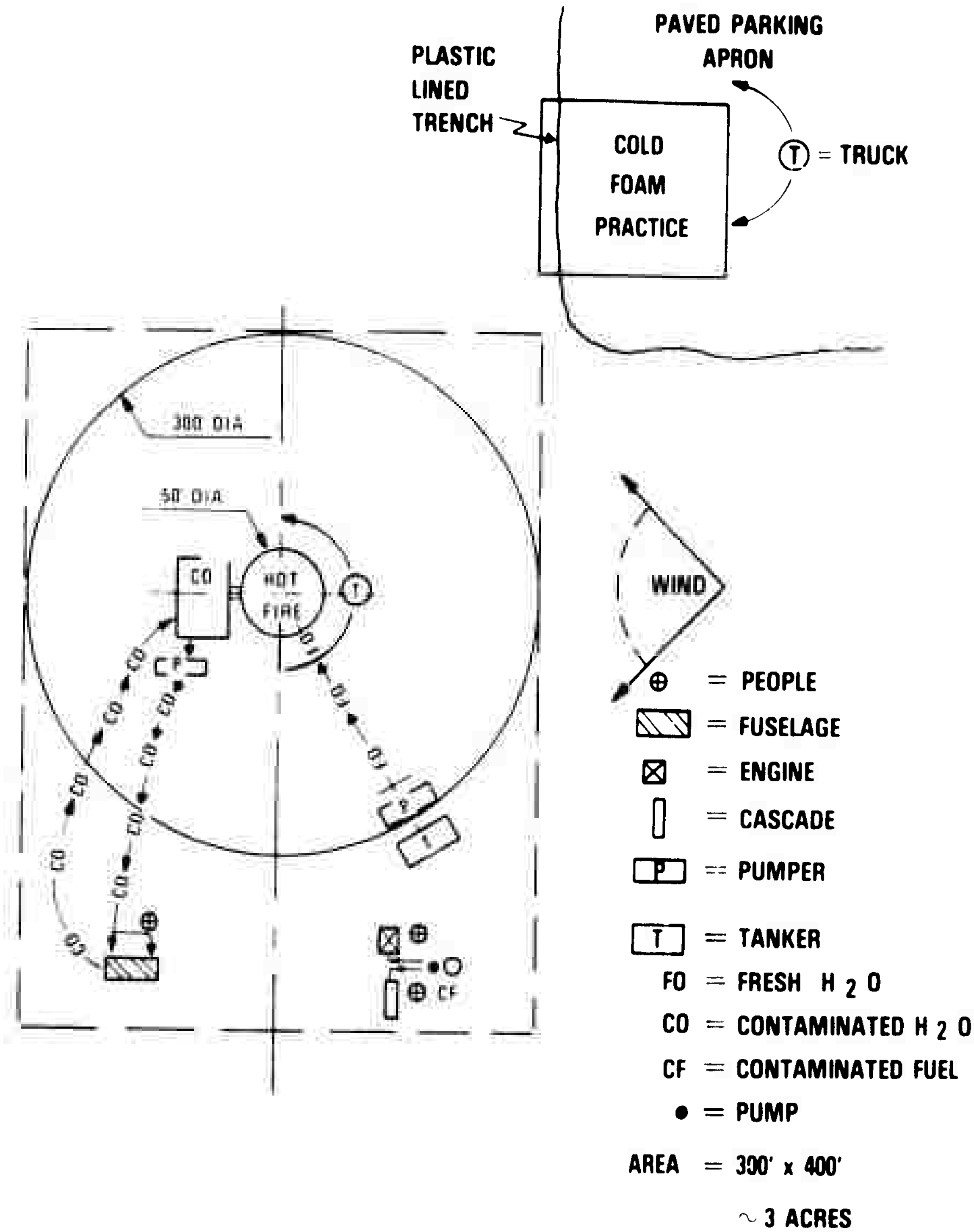


FIG. 7.1 SPARTAN FACILITY

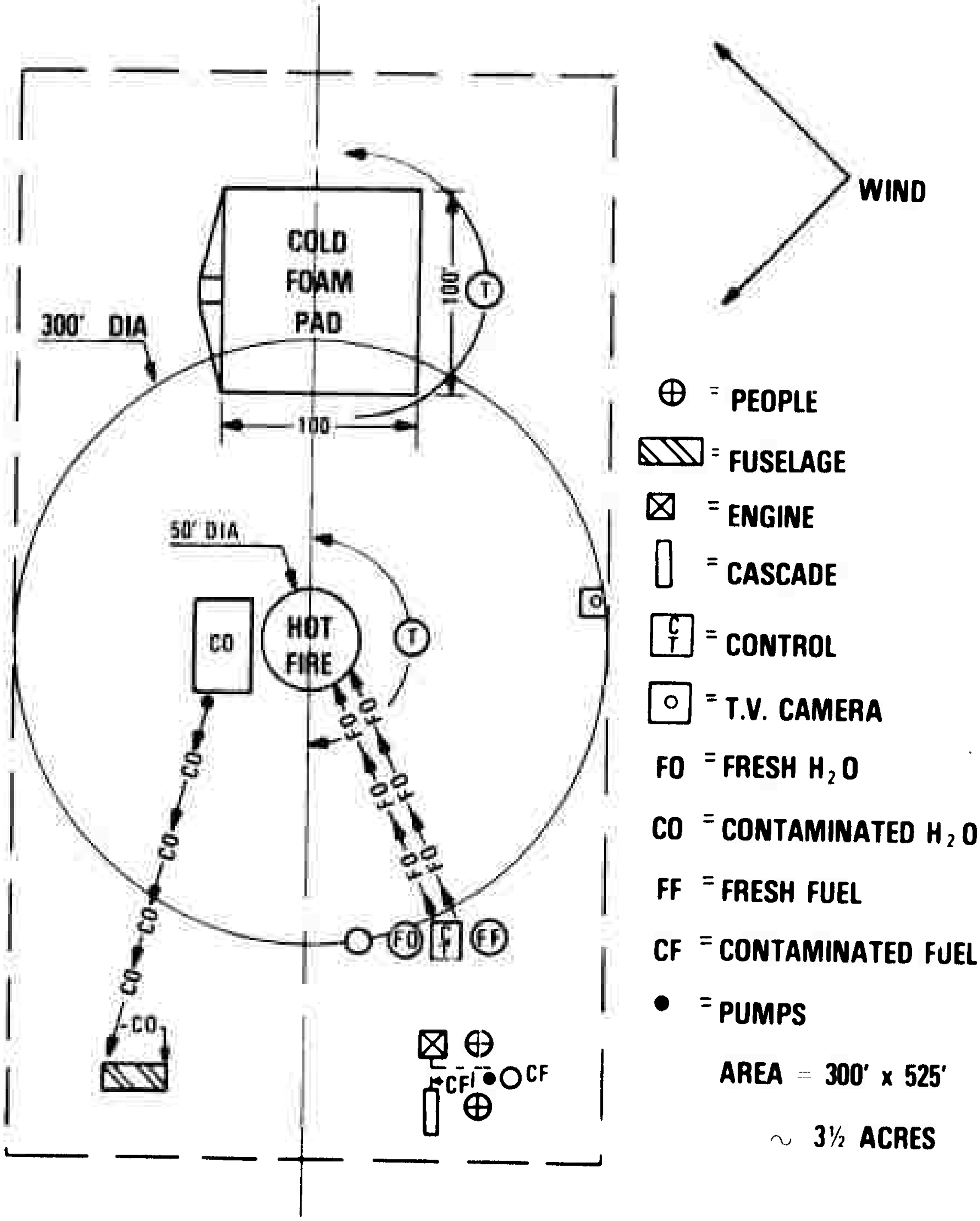


FIG. 7.2 MODEST FACILITY

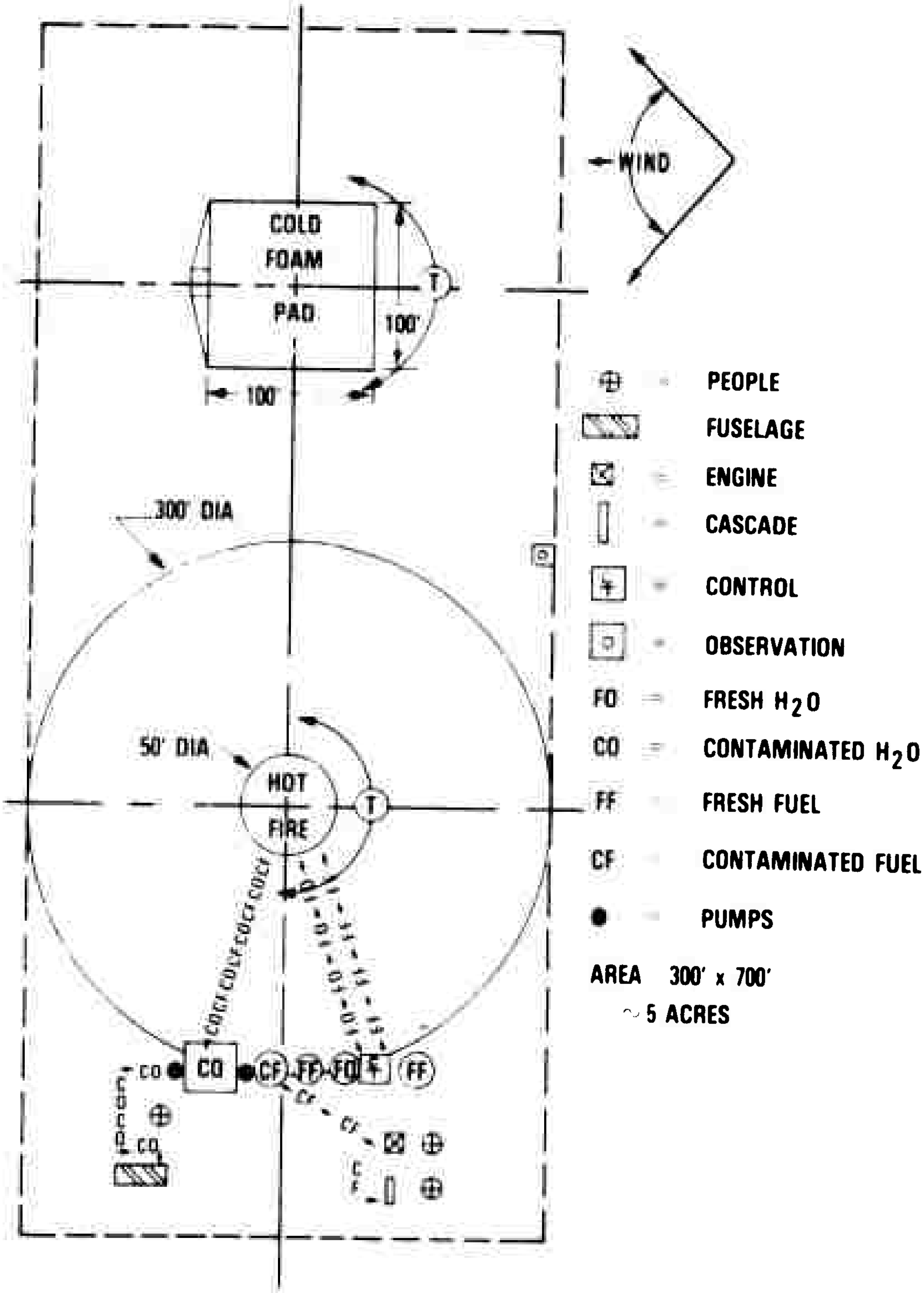
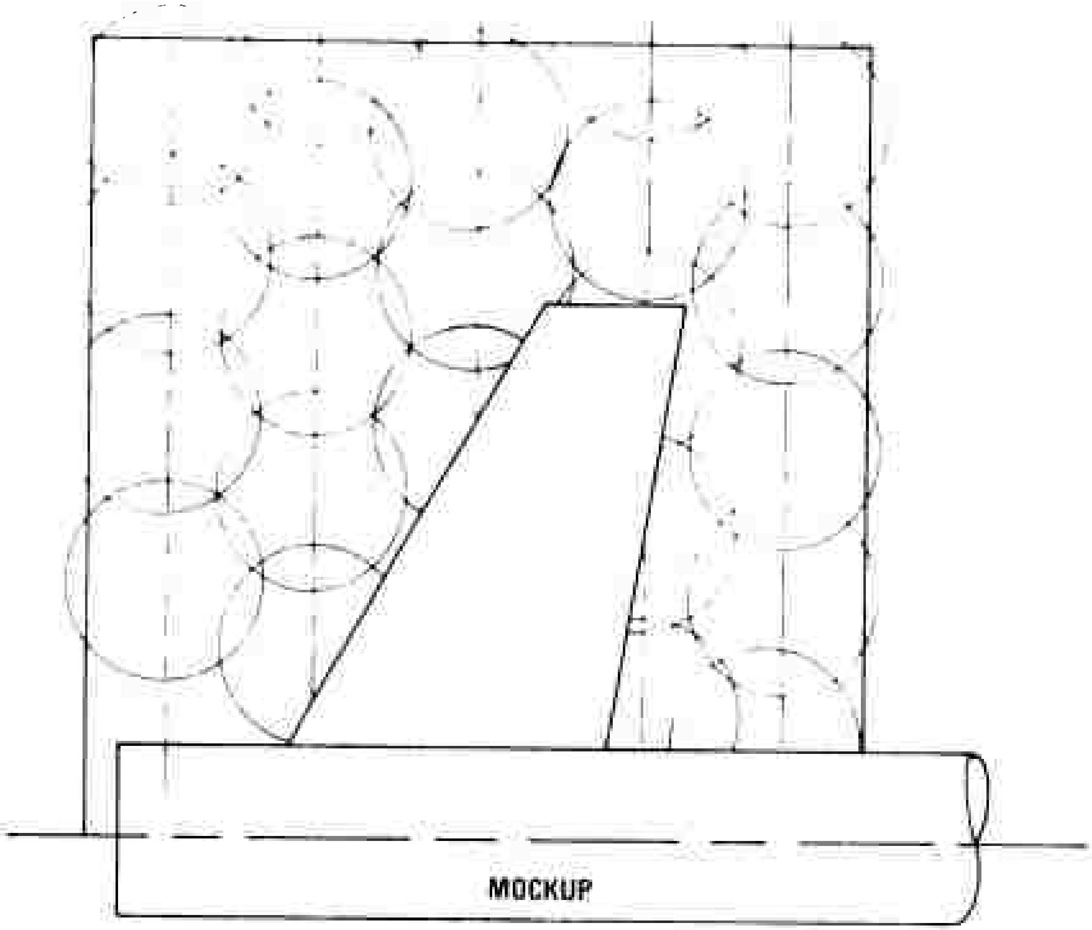


FIG. 7.3 SOPHISTICATED FACILITY



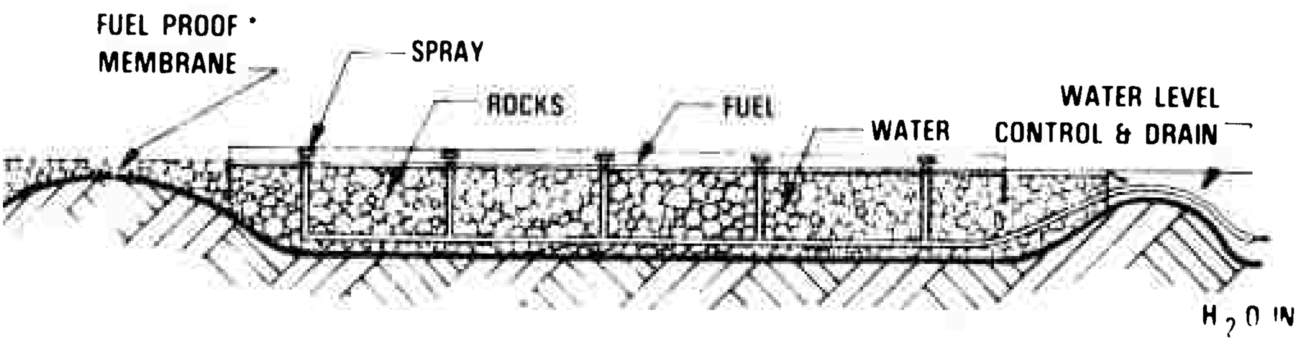


FIG. 7.4 SELF HELP KIT FOR "SPRAY WATER" POOL FIRES KIT CONTAINS MEMBRANE, PLUMBING CUT TO SIZE AND ALL CONTROLS. ROCK AND LABOR SUPPLIED LOCALLY

TABLE 2.1
AIRCRAFT FIRE ACCIDENT SUMMARY
1969-1974

CLASSES OF FIRES	INCIDENCES INVOLVING FIRE: AIR FORCE	NAVY	CIVILIAN	CAUSE: A/C CRASH OR COLLISION (AF NAVY CIV)	CAUSE: DEFECTIVE COMPONENT OR MAINTENANCE (AF NAVY CIV)	CAUSE: NOT REPORTED (AF NAVY CIV)	PHASE OF OPERATION: TAKE OFF (AF NAVY CIV)	PHASE OF OPERATION: IN FLIGHT (AF NAVY CIV)	PHASE OF OPERATION: LANDING (AF NAVY CIV)	PHASE OF OPERATION: ON GROUND MAINTENANCE (AF NAVY CIV)	EXTENT OF INJURIES: NOT REPORTED (AF NAVY CIV)	EXTENT OF INJURIES: NONE (AF NAVY CIV)	EXTENT OF INJURIES: MINOR (AF NAVY CIV)	EXTENT OF INJURIES: MAJOR (AF NAVY CIV)	EXTENT OF INJURIES: FATAL (AF NAVY CIV)	EXTENT OF FIRE DAMAGE: NOT REPORTED (AF NAVY CIV)	EXTENT OF FIRE DAMAGE: NONE (AF NAVY CIV)	EXTENT OF FIRE DAMAGE: MINOR (AF NAVY CIV)	EXTENT OF FIRE DAMAGE: SUBSTANTIAL (AF NAVY CIV)	EXTENT OF FIRE DAMAGE: TOTAL LOSS (AF NAVY CIV)
CLASS A																				
1. COMPARTMENT FIRES																				
PASSENGER QUARTERS	1	4	54	1 29	3 18	1 7	7	1 2 20	20	2	4	1 4	16	18	16	9		3 9	11	1 1 25
CREW QUARTERS	3	19	45	1 1 32	2 13 8	5 5	1 1 10	2 7 14	3 20	8 1	10	19	15	6	3 14	1 3		8 3	7 2	3 3 10
CARGO HOLDS			19	12	3	4	6	4	6	3	15	2	2			8		5	5	1
2. BRAKE AND TIRE FIRES	2	51	28	18 1	2 29 14	4 13	14 13	2 4	1 21 7	1 14 3	3 1	1 46 2	1 19	2 6		2	5	1 46 12	1 4 8	1 1
3. A/C STRUCTURAL COMBUSTIBLES (PLASTIC WING AND FUSELAGE COMPONENTS)	9	69	73	6 5 49	3 55 11	9 13	4 10 13	2 25 11	3 10 38	24 11	6 2	5 58	2 27	2 4 17	1 27	1 9		34 12	4 20 14	5 14 38
CLASS B																				
1. ENGINE	4	202	103	1 8 1	3 174 49	20 53	1 80 11	1 57 43	29 32	2 36 17	4 3	3 183	1 90	12 10	1 2	20	1 22	86 42	3 83 17	1 32 2
2. FUEL SYSTEM	6	48	18	2 12	4 31 2	5 16	1 10 5	1 11 4	3 10 8	1 17 1	2 5 12	4 25 2	12 1	2	4 3			16 3		4 22 5
3. LUBRICATING SYSTEM		3			2	1		2	1			3						2		
4. HYDRAULIC SYSTEM	2	25	22	1 1	1 23	1 2	2	11 1	2 7 1	5	1 1 2		1		1	1 1		18		3 2
CLASS C ELECTRICAL																				
1. POWER		22	4		20 2	2 2	2	11 1	1 2	8 1		21	3	1	1	1	4	13 2		1
2. ELECTRONICS, INSTRUMENTATION, COMMUNICATION, HEATER	2	72	6	1 1	1 56 2	1 15 3	11	33	1 9 2	1 19 4	2 3	1 70	1 2		1	2		61 1		1 1
CLASS D WEAPONS AND MUNITIONS		5			5			1		4		4		1				1	3	1

TABLE 5.1

ADVANTAGES AND DISADVANTAGES OF VARIOUS TRAINING FACILITY OPTIONS*

OPTIONS AND CHARACTERISTICS	Disruption of station schedule	Equipment complications	Quantity of training readily available	Opportunity for most efficient instruction	Uniform evaluation and certification of firemen	Total initial construction costs	Anticipated use factor for same total training	Operation and other training costs; e.g. travel, overtime, etc.
1. Training goes to the Firemen								
(a) No one leaves the station, all firemen are available for emergencies.								
(b) Each crew trains as a team with own equipment and provides own maintenance								
• Option 1 A training facility at each station	A	A	A	H	H	H	H	A
• Option 2 A traveling facility goes to each station	B	B	B	G	G	B	B	B
2. Firemen go to training								
(a) Firemen leave station either individually to a regional center or as a crew to a neighboring station for training.								
(b) Equipment used belongs to and is maintained by training center.								
(c) When cooperation involves several services or civilian stations the question of vehicle compatibility arises.								
(d) • Option 3 Neighboring Navy stations e.g., within 100 miles share a training center.	G	D	E	D	D	F	F	E
• Option 4 Neighboring DOD and/or civilian stations share a training center	H	F	F	C	C	C	D	F
• Option 5 A few regional training centers serve the entire country	F	H	H	A	A	A	A	H
3. Combination options where some training accrues locally and some at shared facilities.								
• Option 6 Combination of Option 1 or 2 with 3	D	C	C	F	F	G	G	C
• Option 7 Combination of Option 1 or 2 with 4	E	E	D	E	E	E	E	D
• Option 8 Combination of Option 1 or 2 with 5	C	G	G	B	B	D	C	G

*Letters indicate estimated ordering of Options from most advantageous (A) to the least (G). However, no quantitative evaluation of the various pros and cons is implied.

TABLE 5.2

NAVY AND MAJOR COMMERCIAL AIRPORTS

NAVY (+ USMC) ONLY						NAVY AND AIRFORCE		
100 n mi radius			150 n mi radius			100 n mi radius		
Example Regional Site	Number of Stations Served	Average Travel Distance	Example Regional Site	No of Stations Served	Average Travel Distance	Example Regional Site	Number of Stations Served	Average Travel Distance
Location		(n miles)	Location		(n miles)	Location		(n miles)
Brunswick NAS	1	0	Brunswick NAS	2	57.8	Pease AFB	5	59.7
Glenview	1	0	Glenview	1	0	Dover AFB	7	56.4
Dallas	1	0	Dallas	1	0	Chase	5	51.5
Corpus Christi	3	24.1	Corpus Christi	3	24.1	Carswell AFB	3	39.3
Key West	1	0	Key West	1	0	Key West	2	89.0
Jacksonville	2	12.0	Jacksonville	3	54.5	Jacksonville	3	54.5
Cherry Pt	2	28.8	Cherry Pt	2	28.8	Patuxent River	5	55.8
Memphis	1	0	Memphis	1	0	Meridian	3	51.3
Atlanta	1	0	Atlanta	1	0	Atlanta	2	91.4
Pensacola	2	9.6	Pensacola	4	75.6	Pensacola	6	37.4
Fallon	1	0	Fallon	1	0			
China Lake	1	0	China Lake	2	57.8	Point Mugu	8	71.6
Moffett Field	2	26.5	Moffett Field	2	26.5	Castle AFB	8	68.6
Whidby Is	1	0	Whidby Is	1	0	Whidby Is	2	36.1
Miramar	6*	34.1	Miramar	8	60.6	Norton AFB	11	56.9
El Centro	5*	56.3	Andrews NAF	7	88.0			
Los Alamitos	6*	50.5				14 locations	70 stations served (40 Navy & 30 AF)	Average travel distance
El Toro	6*	47.8						
Lemoore	1	0						
Warminster	3	25.7						
New Orleans	1	0						
Meridian	1	0						
Patuxent River	4	51.7						
South Weymouth	1	0						
min no 22 locations	40 stations	average travel distance 15 n mi	16 locations	40 stations	average travel distance 29½ n mi			

*These 100-mi-radius circles overlap There are a total of only 9 stations represented

TABLE 5-2 (CONTINUED)

NAVY AND MAJOR COMMERCIAL AIRPORTS

Within 100 naut. mile radius

(Two Examples Only)

Site Location	Number Served	Average Travel Distance (n. mi)
Warminster NAS (New York Area)	20	51.6
Alameda NAS (San Francisco Bay Area)	20	50.1

TABLE 5.3

HYPOTHETICAL ECONOMIC ANALYSIS OF VARIOUS TRAINING FACILITY OPTIONS

OPTION FROM TABLE 5.1	NUMBER REQUIRED	TOTAL CONSTRUCTION COSTS, MILLIONS			YEARLY RECURRING COSTS TO REMOVE FIREMEN	COST DIFFERENCES BETWEEN OPTIONS* MILLIONS			YEARS FOR RECURRING COSTS TO CANCEL THE OPTION/CONSTRUCTION COSTS		
		SPARTAN S_n	MODEST M_n	SOPHISTICATED SO_n	Y	$2 - S_n$	$4 - M_n$	$8 - SO_n$	$\frac{2 - S_n}{X}$	$\frac{4 - M_n}{Y}$	$\frac{8 - SO_n}{Y}$
1	40	2	4	8	0	0	0	0	S	M	So
2	7	.5	-	-	.05	1.5	-	-	30	-	-
3	22	1 1	2.2	4.4	.52	.9	1.8	3.6	1 7	3.4 1.3	7
4	14	.7	1.4	2.8	.97	1.3	2.6	5.2	1 3	2.7	5 4
5	8	-	-	1.6	2.4	-	-	6.4	-	-	2 7
6	40** 22***	6 $\frac{.77}{1.4}$	1 $\frac{1.65}{2.7}$	2. $\frac{3.3}{5.3}$	.52	.6	1.3	2.7	1 15	2.5	5.2
7	40** 14***	.6 $\frac{.49}{1.1}$	1 $\frac{1}{2}$	2. $\frac{2.1}{4.1}$	.97	.9	2	3.9	.93	2.1	4 3
8	40** 8***	-	-	2. $\frac{1.2}{3.2}$	2.4	-	-	4.8			2

* DIFFERENCE IN CONSTRUCTION COSTS BETWEEN OPTION 1 i.e THE MOST EXPENSIVE, AND THE OTHER OPTIONS
** SEPARATE FACILITIES FOR THIS OPTION
*** SHARED FACILITIES FOR THIS OPTION

TABLE 5.3 (CONTINUED)

1. The costs of the individual devices in the training facility are guessed to be as follows:

ITEM	SPARTAN		MODEST	SOPHISTICATED
	Stationary	Mobile		
(a) Cold fire training pot	0	0	5	20
(b) Fuselage fire trainer for class A & C fires	10	20	25	50
(c) IITRI "Spray Water" pool fire	25	40	50	105
(d) Engine fire	10	10	13	15
(e) Cascade fire	5	5	7	10
	50K	75K	100K	200K

2. The number of units required is based on table 5.2 except for options 5 and 8 where 2 units would be required at each regional center. Where a spartan or modest system is not priced under a particular option, the simpler system is assumed to be inadequate.

3. The total amount of training is the same for all options, therefore, the costs for fuel, agent, water, vehicle operation and maintenance is assumed constant and is not included.

4. Facility life times are assumed to be 10 years for items b, d, e, and the movable fire pit and 25 years for the fixed IITRI pool. No allowance is included for maintaining the equipment.

5. All options except 4 and 8 are assumed to employ existing vehicles. Regional training centers will require additional vehicles, a minimum of two per center at about 125K for a P-4 or 1 million dollars for 8 vehicles.

6. Recurring costs are primarily the wages and travel costs involved in taking firemen to the training. To minimize the costs, only the 2400 men assigned full time to aircraft fire and rescue are included. The average station complement is assumed to be 60 men at a daily cost including overhead and

TABLE 5-3 (CONTINUED)

burden of \$120 per man. Travel costs are assumed to be 12 cents per mile for local travel and 6 cents per mile for commercial flights. If charges are made only for the men who leave their stations, the costs per option are assumed as follows.

Option 1 No charge

Option 2 No charge for manpower; moving the equipment is assumed to cost about \$300 per move for 4 x 40 moves $\sim$ 50K.

Option 3 Firemen from 18 stations go an average of 30 miles round trip and cost a day's pay four times a year.

60 x 18 x 4 x 120 = .52 million wages

assuming 5 men per vehicle traveling

12 x 18 x 4 x 30 x .12 = .0015 million

Option 4 Firemen from 33 navy stations move an average 100 miles round trip four times a year.

60 x 33 x 4 x 120 = .95 million wages

12 x 33 x 4 x 100 x .12 = .019 million

Option 5 Assume 2400 firemen go 2000 miles round trip once a year and consume 4 days per trip.

2400 x 4 x 120 = 1.15 million wages

2400 x 2 00 x .06 = .3 million

Assume each center requires a minimum of 4 men to operate the center of a cost and overhead of 60K per man

4 x 4 x 60 = .96 million

Option 6, 7, 8 Training with items a, b, and c are done at the home station but the travel to the shared station costs the same as option 3, 4, and 5 respectively.

7. Because of the rough estimates, no discount factors are considered in the recurring costs.

TABLE 6.1

SMOKE ABATEMENT FOR OPEN AREA AIRCRAFT FIRE RESCUE TRAINING FIRE REQUIREMENTS

1. Fire must be of sufficient intensity to cause serious efforts in the control of a rescue path and coordination of crew members.
2. Fire must possess sufficient realism to demonstrate the effectiveness and proper application of extinguishing agents (AFFF, PKP, CO2, etc.) and the agent application device being utilized by the trainee.
3. Control, by the training officer, of the fire size, intensity, and location in relation to the fuselage mock up unit should be possible.
4. Three dimensional (raining fuel) fires, i.e. simulated wing tank rupture, etc., should be incorporated.
5. Provisions should be incorporated to simulate hidden and hard to extinguish fires, i.e. under wing, interior of fuselage mock up unit, etc.
6. The introduction of temporary obstructions, including materials with different fire characteristics, i.e. tires, magnesium, etc. should be possible.
7. A minimum fire area 50' in diameter (approx. 2000 sq. ft.) is required.
8. It must be possible to completely encircle the fuselage mock up unit with fire.
9. The area around the fire site should be of sufficient size and surface condition to permit pump and roll mode of operation with a minimum of two vehicles. Minimum size, including the fire area, should be 300' in diameter (approx 1 1/2 acres).
10. More than one approach path to the fire site for firefighting vehicles must be provided.
11. Approach through the fire area to the fuselage mock up unit for simulated rescue operation by crew members (walking) must be possible, with assurances of safe footing under firefighting conditions.

TABLE 6.2

TYPICAL AIRCRAFT DIMENSIONS

Aircraft Type	Overall Length Ft.	Wing Span Ft.	Height *	
A - 1	39	50	10	C
A - 4	38	27 1/2	10	C
A - 6	55	53	16	O
A - 7	47	39	7	C
F - 4	38	38 1/2		
F - 8	55	36	16	O
T - 28	32	41	13	O
T - 39	44	45	16	O
F - 9	48	34	12	O
F - 14	61	64		
A - 5	76	53	10	C
A - 3	76	70 1/2	10	C
C - 2	56	80 1/2		
C - 9	119	93	27 1/2	O
C - 4	64 1/2	95	18	O
C - 54	93 1/2	117 1/2		
C - 118	107	117 1/2	29	O
C - 121	98	132 1/2	38	O
P - 2	92	101	29	O
P - 3	117	100	12	C
S - 2	43 1/2	72 1/2	16	O

*C = to cockpit

O = overall height

TABLE 7.1

WATER, FUEL AND AGENT REQUIREMENTS FOR VARIOUS TRAINING DEVICES ±

(ONE EXERCISE)

	Enclosure Fire	Cold Fire Bed	Hot Fire Bed	Engine	Spray or Cascade
Initial H_2O Required	<100 gal*	150-600 gal*	~200 gal†-spray +200 gal for foam	0 0	0 0
Used or Contaminated	0	0	~400 gal	0	0
Fuel Burned	< 1 gal	0	150 gal	<10 gal	<15 gal
Initial Agent	< 50 gal* H_2O	9-36 gal AFFF concentrate	~12 gal AFFF concentrate	30 lbs PKP	50 lbs
Diluted & Contaminated Agent	0	0	~12 gal AFFF	30 lbs PKP	50 lbs PKP

*Can use contaminated water from the Hot Bed

†Does not include H_2O or fuel to fill pond initially

±Based on 30 second pre burn,
30 second extinguishment, application density 12 gal/100ft,^{2} Burning rate 30mm/min

TABLE 7.2

WATER, FUEL AND AGENT REQUIREMENTS FOR VARIOUS FACILITIES*
CATEGORY OF FIRE

	Spartan	Modest	Sophisticated
No. of Pool Fires/week	1 to 5	5 to 20	>20
H_2O to be Reclaimed or Reused for Smoke Abatement	200-1000 gal	1000-4000 gal	>4000 gal
for Suppression	200-1000 gal	1000-4000 gal	>4000 gal
JP4 Burned/week	150-750 gal	750-3000 gal	>3000 gal
AFFF Concentrate	6-30 gal	30-120 gal	> 120 gal

*For Water Spray Fire per week

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